Number 143  Subject Areas: Highway Design  May 1973
Pavement Design
Pavement Performance
Maintenance, General
Highway Safety
Road User Characteristics
Traffic Control and Operations
Traffic Measurements

RESEARCH PROBLEM STATEMENTS

COMMITTEE ACTIVITY

OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES
Harold L. Michael, Chairman
Group 3 Council
Purdue University, Lafayette, Indiana

COMMITTEE ON OPERATIONAL EFFECTS OF GEOMETRICS
(As of December 31, 1972)

John W. Hutchinson, Chairman
University of Kentucky
Lexington, Kentucky

K. B. Johns, Staff Engineer

E. N. Burns  Julie Anna Fee  Eugene F. Reilly
Stanley R. Byington  George F. Hagenauer  Neilon J. Rowan
Arno Cassel  Rajendra Jain  Sheldon Schumacher
Robert R. Coleman  Janis H. Lacis  James J. Schuster
B. K. Cooper  Richard A. Luettich  Robert B. Shaw
Joseph C. Corradino  William A. McConnell  James Correll Spencer
James J. Crowley  Joseph M. McDermott  Vasant H. Surti
Harley T. Davidson  Thomas E. Mulinazzi  Paul R. Tutt
John A. Dearinger  John D. Orzeske  Walter C. Vodrazka
John Drake  Stuart R. Perkins  Jason C. Yu

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL  NATIONAL ACADEMY OF SCIENCES - NATIONAL ACADEMY OF ENGINEERING
2101 CONSTITUTION AVENUE, N.W.  WASHINGTON, D.C.  20418
INTRODUCTION

One of the continuing functions of Highway Research Board Committees is the stimulation of research. One of the techniques for doing this has been to develop statements of problems known by Committee members to need research attention. Wide dissemination of these problem statements places them at the disposal of (1) a variety of officials responsible for developing and funding research programs, (2) a variety of researchers in the academic and business communities, and (3) an appropriate segment of the professionals practicing or experimenting in the areas covered.

The scope of the Committee on Operational Effects of Geometrics is "geometric design as related to traffic operations and safety". The Committee members' awareness of traffic operations and safety problems leads them often to some indication of a relationship to one or more design variables. The problem statements in this Circular, therefore, may touch upon the scopes of several other committees in both Groups 2 and 3. It is for this reason that the Circular is being very widely distributed, even though some readers may have a direct interest in only a few of the statements presented.

PRIORITY RATING PROCEDURE

Twenty-six problem statements related to the operational effects of geometrics were circulated to the Committee for priority ranking. Chairman Hutchinson's instructions required that, in addition to ranking, committee members assign hypothetical research fund amounts in increments of $10,000 to the extent of one million dollars.

Within two and one-half months, eighteen Committee members returned the results of their ranking to a task force charged with analyses of the ranking. The task force used three techniques in their work:

1. Priority ranks were computed from the averages for each statement.
2. Fund magnitude ranks were computed from the money sums for each statement.
3. Individual priority rankings were grouped into a top 5 and a top 10 list of statements.

The task force developed a best consensus from the material submitted. In the analysis of the priority and fund ranking, it was found that the resulting order was essentially the same.

Comparison of the statement's ranking using the priority and top 5/top 10 techniques showed good agreement on those statements which belong in the top 5 and a divergence of opinion for the second five. In fact, the divergence of opinion in the second five initially caused three of the twenty-six statements to tie for tenth place using the top 5/top 10 technique. All twelve statements were reconsidered at the committee meeting.

As a result of this analysis, the problem statements have been rated in three priority categories:

A. The top 4 statements
B. The second 5 statements
C. All other statements
The following table lists the results.

### RESEARCH PROBLEM STATEMENTS

<table>
<thead>
<tr>
<th>Priority Category</th>
<th>Problem Statement Number</th>
<th>Titleerek</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>Safety Benefits of Higher Level Design Standards</td>
</tr>
<tr>
<td>A</td>
<td>4</td>
<td>Communications with Drivers</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td>Effects of Weather on Accidents, Driver Behavior and Traffic Operations</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>Effects of Illumination on Traffic Operations on Non-Controlled Access Roads</td>
</tr>
<tr>
<td>B</td>
<td>9</td>
<td>Skid Resistance Range of Bituminous Pavements</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>Barriers on Narrow Medians</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>Visibility Considerations of Highway Medians</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>Road User Behavioral Studies</td>
</tr>
<tr>
<td>B</td>
<td>8</td>
<td>Application of Curved Roadway Cross-Sections to Freeway Entrance/Exit ramps</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>All other statements</td>
</tr>
</tbody>
</table>
I. PROBLEM NO. 1 - PRIORITY CATEGORY A

II. NAME OF PROBLEM - SAFETY BENEFITS OF HIGHER LEVEL DESIGN STANDARDS

III. THE PROBLEM - Since the enactment of the 1966 Highway Safety Act, 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 which would normally be clear. These improvements are being made to assist the driver of the out-of-control vehicle which has left the traveled way, to bring his vehicle safely to a stop with a minimum of damage or injury or to safely re-enter the traffic stream. Many miles of these improved highways, both two-lane and multi-lane, are open to traffic. There should now be a direct comparison 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 could be determined.

IV. RESEARCH PROPOSED - The objective of this research is to measure the effectiveness of upgrading design standards on the safety of highways by:

1. Comparing the accident rates (and severity) on highways constructed (or upgraded) to meet new safety standards with existing highways which 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, terrain, etc., should be similar for both "new" and "old" highways being evaluated.

2. Comparing the relative safety of "new" and "old" design of sub-elements such as guard rail, shoulder width, flatter slopes, clear area width, etc.

3. Including cost effectiveness analyses to measure the benefit received from greater cost required to provide a higher level of safety.

Studies should include both low and high volume highways in both urban and rural areas.

V. PROBLEM ESTIMATE - This research would be limited principally to analysis of accident reports, construction cost data, and construction plans already on file. Some field measurements would be required, where as-built plans are not available. In addition, field inspections would be necessary at each site selected to measure certain geometric elements or physical conditions not available from plans or accident reports. Data should be collected from at least four states on both two lane and multi-lane highways.

Amount Recommended - $260,000

Contract Term - 2 Years

VI. URGENCY - It is believed essential that all highway administrators and safety officials should be able to relate, both quantitatively and qualitatively, the higher levels of safety achieved to the higher level of expenditures required, for safety features now being included in design.
I. PROBLEM NO. 2 - PRIORITY CATEGORY A

II. NAME OF PROBLEM - EFFECT OF ILLUMINATION ON TRAFFIC OPERATIONS AND SAFETY ON CONVENTIONAL ROADS

III. THE PROBLEM - Night time 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 which are not so lighted. Many factors have been shown to affect the night time driving task. While 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, the presence of reflective signs, markings and delineators and by 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 relationships between intensity of illumination and accident experience. In qualitative terms, comparing accident experience for various night time lighting conditions to daylight, the absence of street lighting produces twice the accident experience; with "poor" street lighting, it is sixty percent higher; and with "good" street lighting, it is thirty percent higher. A seven year old California study concluded that continuous low intensity illumination ranging from 0.20 to 0.35 foot candles is not effective in reducing night accidents.

Presently there are two 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 relationships between 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 such environmental variables as roadway reflectance and geometry.

IV. RESEARCH PROPOSED - The objectives of the proposed research should be:

1. Determine the environmental factors which affect night visibility and their relationships to the driving tasks.

2. Determine the effect of the uniformity and intensity of roadway illumination on such operating and safety characteristics as speed, lateral placement, headways and accident experience.

Scope: The research should relate to conventional roads. Varying visual acuity and behavioral traits in the driving population should be accounted for but are not the immediate subjects of this research. Identification and isolation of the various environmental factors including roadway reflectance and geometry should be carefully controlled to provide for basic understanding of the variables affecting the night time driving tasks and consequent vehicular behavior.
I. PROBLEM NO. 3 - PRIORITY CATEGORY A

II. NAME OF PROBLEM - EFFECTS OF WEATHER ON ACCIDENTS, DRIVER BEHAVIOR AND TRAFFIC OPERATIONS

III. THE PROBLEM - 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.

IV. RESEARCH PROPOSED - The objectives of this research should be:

1. To investigate the effects of weather conditions on: accidents and accident rates; driver judgements 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. To 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, make and age, and driver age, sex and experience.

3. To analyze these factors through observational and experimental studies.

4. To analyze accident reports to determine the effect of weather in accident causation in a variety of study sites and develop improved accident reporting systems which provide for consideration of weather.

5. To determine significant combinations of driver, vehicle, weather and road characteristics which influence accidents and traffic operations.

6. To assess possible roadway, vehicle and driver remedial measures to reduce the effects of weather on accidents and traffic operations.

Scope: The research should include all types of roads.

V. PROBLEM ESTIMATE

Amount Recommended - $150,000
Contract Term - 2 Years

VI. URGENCY - This is a constant problem that is subject to constant cursory observation but the specific, detailed, substantiated study should be performed as soon as possible to avoid further possible avoidable accidents.
I. PROBLEM NO. 4 - PRIORITY CATEGORY A

II. NAME OF PROBLEM - COMMUNICATION WITH DRIVERS

III. THE PROBLEM - Making the driver aware of regulatory, directional, roadway condition information in a non-distracting, completely adequate manner.

IV. RESEARCH PROPOSED - The objectives of the research should be:

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 or audible means or others.

3. Determine driver reaction and subsequent vehicle operation because of communication, and concern should be directed to reactions to signals, time required to comprehend any signal, the depth of absorption in signal comprehension and attention diverted from vehicle operation.

Scope: The research should be performed first for expressway type problems.

V. PROBLEM ESTIMATE

Amount Recommended - $250,000
Contract Term - 1 Year

VI. URGENCY - This is a particularly pressing problem that requires immediate work.

I. PROBLEM NO. 5 - PRIORITY CATEGORY B

II. NAME OF PROBLEM - VISIBILITY CONSIDERATIONS OF HIGHWAY MEDIANS

III. THE PROBLEM - In order to keep traffic operations in an efficient and safe manner, the physical alignment of the highway median must be recognized by the vehicle operator at the earliest possible moment. A median can become more of a hazard than an aid unless it is plainly visible at all times. The satisfactory level of median visibility should therefore be considered as an essential safety feature of the highway facility.

However, the effective measures of improving the median visibility, particularly during the night time hours, have not been established on a national basis; they have been left to the individuals' discretion. As is too often the case, if there is a need to improve the night visibility of some median locations, no standard method is readily available for adoption. This indicates that specifications for median visibility under various situations are urgently needed and should be adopted uniformly throughout the nation.

For obvious reasons, it is essential to conduct an in-depth study which is intended 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 as well as the plans of the future facilities, the determined methods that will enhance the median visibility must be utilized correctly in order to avoid all possible traffic accidents due to the inadequate median visibility on divided highways.

IV. RESEARCH PROPOSED - The objectives of this research should be:

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

V. PROBLEM ESTIMATE

Amount Recommended - $75,000
Contract Term - 18 Months

VI. URGENCY - Traffic operation personnel in states are making decisions in this area today, and early guidance is desirable.

I. PROBLEM NO. 6 - PRIORITY CATEGORY B

II. NAME OF PROBLEM - BARRIERS ON NARROW MEDIANS

III. THE PROBLEM: Median barriers are installed to make highways safer by reducing accident severity. Properly designed installations accomplish this goal by:

1. preventing out-of-control vehicles from entering the opposing stream of traffic, and
2. redirecting out-of-control vehicles to a direction parallel to the flow of traffic.

Even though the median barrier is a recognized safety device, are we sacrificing too much of the capacity of the facility to provide this additional safety?

What effect does a rigid median barrier placed in a narrow median (approximately three feet in width) have on the capacity of the roadway?

We know that objects placed closer than six feet to the edge of the pavement have a definite restricting effect on the capacity of the adjacent lane. However, it is also believed that a continuous restriction, such as a barrier guardrail, is probably less restrictive than a series of separate obstacles.

IV. RESEARCH PROPOSED - A Study should be conducted to determine the condition at which median barriers must be provided in narrow medians, considering traffic volume, speeds, percent turns, accident experience, etc. along with the effect on the overall capacity.
V. PROBLEM ESTIMATE

Amount Recommended - $80,000
Contract Time - 1 Year

VI. URGENCY - This problem is urgent because of the following reasons:

1. Cost of right-of-way can be reduced through the use of narrow medians.

2. Additional lanes are needed on many freeways and expressways and the only way to achieve this is to build the additional lanes in the existing median with a barrier.

I. PROBLEM NO. 7 - PRIORITY CATEGORY B

II. NAME OF PROBLEM - ROAD USER BEHAVIORAL STUDIES

III. THE PROBLEM - Within our conglomeration of highways and streets, are facilities of all vintages; some are ultra-modern, some are modern (designed 10 years ago), some are old and some are unrealistically ancient, from the standpoint of geometric design; but all are still in use. Generally, the older the facility, the higher the level of regulation and control imposed on the road user, in spite of the old addage to the effect that "you can design it so that it cannot be signed, signaled and marked." As we go on building newer and better facilities, we constantly increase our inventory of obsolete designs with slower traffic movement and with frictions caused by circulating traffic, parking and unparking, truck loading, dense signalization (we have already signalized the entry ramps to major expressways), and channelization... all of which affect the road user by restricting his freedom. Driver reactions to these higher and higher levels of control on our progressively aging facilities are quite varied. Most drivers will accept and recognize the need for such apparent "substitution of control for design," because we obviously can't go back and rebuild everything everytime we make important progress in geometric design. However, a sizable number of drivers place their personal interests first and are willing to violate the regulations which made our accumulating, progressively older designs somewhat workable. It is suggested that 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 of the characteristics and distribution of people of different basic psychological type, different perceptual, motivational and attitudinal profiles is rapidly becoming available. None of this information is being brought to bear heavily upon 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; we have probably addressed ourselves to a type of "average driver" who doesn't actually exist.

- 8 -
IV. RESEARCH PROPOSED - The objectives of this research should be:

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

2. Determine (quantify) how much information a driver can handle.

3. Define the driver for which roadways and traffic control devices should be designed, and

4. Quantify the informational band currently placed on drivers under various environmental, roadside and traffic flow conditions.

This effort should also include development of techniques, and subsequent employment, to distinguish failures resulting from 1) inadequate transmission and reception of information, and 2) improper control.

V. PROBLEM ESTIMATE

Amount recommended - $400,000  
Contract Term - 2 1/2 Years

VI. URGENCY - There is particular need to identify the level or rate at which the traffic engineer can provide information upon which drivers must and will respond.

I. PROBLEM NO. 8 - PRIORITY CATEGORY B

II. NAME OF PROBLEM - APPLICATION OF CURVED ROADWAY CROSS-SECTIONS TO FREEWAY ENTRANCE/EXIT RAMPS

III. THE PROBLEM - Normal design for the cross-section curvature of freeway entrance/exit ramps is a flat lane, either level or super-elevated, 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 utilized. The neutral speed, wherein the vehicle has no centripetal side force, is of course a function of the radius and pavement superelevation.

Freeway entrance/exit ramps have become the key design variable in at least four aspects of highway construction:

1. As the determining factor of traffic operation in urban applications, with increasing efforts toward effective two-lane designs.

2. A major land use requirement, particularly in complex intersections of major highways.
3. A significant construction cost variable, estimated to account for as much as 10 percent of rural and up to 50 percent of urban paving areas.

4. A prime accident location or causal factor, with vehicles exiting at greater than neutral speeds or attempting to merge at inappropriate entrance speeds.

Privately owned automobile proving ground test tracks utilize 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.

IV. RESEARCH PROPOSED - The objectives of this research should be:

1. Optimize entrance/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 multi-lane applications of the curved cross-sections.

3. Investigate existing construction equipment and/or recommend efficient techniques and equipment to minimize the construction cost and time for such curved cross-sections.

Scope: The research should consider primarily single lane ramp designs diverging to wider curve cross-sections, but the capability for more viable multi-lane ramps should be explored on a secondary basis. Projection of the new designs should be based on contemporary data and traffic simulation models.

V. PROBLEM ESTIMATE

Amount Recommended - $250,000
Contract Term - 2 Years

VI. URGENCY - This problem is of significant importance to topics of freeway saturation and accident causation, as well as construction and land acquisition costs for current and future projects.

I. PROBLEM NO. 9 - PRIORITY CATEGORY B

II. NAME OF PROBLEM - SKID RESISTANCE RANGE OF BITUMINOUS PAVEMENTS AT DIFFERENT SPEEDS

III. THE PROBLEM - Different States employ different standard mixes for bituminous pavements for primary highways. For reasons of economy and because natural construction materials are generally available in most regions, pavements are commonly made of materials locally available in the regions.

To date, Skid Resistance Inventory tests have indicated that:

1. Pavements of the same basic design, when built of different regional materials, result in different ranges of skid resistance.

2. 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 which differs from region to region.
3. Some combinations of materials appear to wear and polish more than others.

4. The 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, with fair certainty, 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.

IV. RESEARCH PROPOSED - The objectives of this research should be:

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 will the skid resistance be degraded under specified volumes of traffic, and

3. Define the seasonal change likely to be experienced in skid resistance of bituminous pavements in the various regions of each State.

The preceding objectives could be achieved by skid testing, with a standard two wheel 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.

V. PROBLEM ESTIMATE

Amount Recommended - $60,000/State
Contract Term - 2 Years

VI. URGENCY - To complement an extensive Skid Accident Reduction research program in the Federally Coordinated Program so as to reduce the frequency and severity of accidents associated with skidding and loss of control on wet pavements.

I. PROBLEM NO. 10 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - MEDIAN BARRIER DESIGN FOR ILLUMINATION

III. THE PROBLEM - A number of types of median barrier fence are in use around the country and most of these perform well. They vary from rigid concrete barriers to deflecting fence and cable installations and most have good and bad features.
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 since the illumination pole will probably not be designed with a breakaway base when placed in the median because of the problems associated with a pole knocked down and into a traffic lane. Illumination poles have been mounted on concrete barriers but the state of the art here is not clearly established.

IV. RESEARCH PROPOSED - The objectives of this project would be to review the possible combinations of median barrier design and illumination pole mounting and to determine an optimum arrangement for various median widths up to about 40 feet.

V. PROBLEM ESTIMATE

Amount Recommended - $150,000
Contract Term - 2 Years

VI. URGENCY - A great deal of work in this area is in progress. A clear determination of the best design is needed.

I. PROBLEM NO. 11 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - HORIZONTAL AND VERTICAL ALIGNMENT DESIGN

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

IV. RESEARCH PROPOSED - The objective of this research is to determine the interaction between vehicle dynamics and road geometry as mediated by driver behavior. Particular attention should be given to the ability of drivers to negotiate curves as influenced by transition geometry and vehicle dynamics. More specifically, this study would involve 1) determining human perception thresholds for lateral, longitudinal and vertical translational motions and yaw, pitch, and roll motions, and 2) determining the sensitivity threshold of the many complex combinations of these individual motions.

Geometrics that should be examined include curvature and superelevation on high-speed turning roadways (as at Major Interchanges), cross-section design on 6 or more lane freeways and in passing zones on two-lane highways, and vertical curvature at railroad/highway grade crossings.

The end result of this research should be 1) established levels of tolerance between the driver and geometric standards pertaining to radius of vertical curvature, length of vertical curvature, and sight distance, and 2) quantitative criteria for properly combining horizontal and vertical alignment design so as to avoid alignment losses, inflexions and curvature changes in humps that cause adverse anxiety reflexes by drivers.

V. PROBLEM ESTIMATE

Amount Recommended - $150,000
Contract Term - 1 1/2 Years
V. URGENCY - When human perception thresholds are better known, the sparse existing limits can be extended, thereby allowing the potential for optimizing roadway alignment by such factors as reduction of curve radii, more efficient utilization of vertical curves and reduced length spiral curvatures.

I. PROBLEM NO. 12 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - EFFECTS OF THE VISUAL INFLUENCES OF HUMAN ENGINEERED OBJECTS ON TRAFFIC OPERATIONS

III. THE PROBLEM - As an aid in future land use planning it would be valuable to know if traffic operations are affected by the visual influences of human engineered objects which are placed off the highway right-of-way. These objects would include such items as buildings or structures which reflect glare or cast shadows, smokestacks which exhaust smoke across bridges and other roadways, etc.

IV. RESEARCH PROPOSED - The objectives of this research should be:

Observe driver behavior under specific situations selected for study, and compare these findings to driver behavior under otherwise normal circumstances.

V. PROBLEM ESTIMATE

Amount Recommended - $100,000
Contract Term - 18 Months

VI. URGENCY - This is continuing research.

I. PROBLEM NO. 13 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - EFFECT OF CLIMATIC PHENOMENA ON TRAFFIC OPERATION

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

IV. RESEARCH PROPOSED - The objectives of this research should be:

1. Determine the extent of the problem before concern is given to the specific effects of individual phenomena.

2. When the extent of the problem is known, study the effects of any given natural phenomena to determine methods of control and/or elimination of the effect.

V. PROBLEM ESTIMATE

Amount Recommended - $100,000
Contract Term - 2 Years
VI. URGENCY - This is a long term observation type research project that would have to be put in second priority. The instances of this effect on traffic operations are few although sometimes tragic.

I. PROBLEM NO. 14 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - AIR POLLUTION - RELATIONSHIPS TO PHYSICAL AND OPERATIONAL VARIABLES

III. THE PROBLEM - When dealing with the problem of air pollution, many different contributors of pollutants must be considered. Industry, jet aircraft, etc., add their emissions to the air. But, the single greatest contributor of pollution to the air is the motor vehicle powered by an internal combustion engine. This 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 which will operate with levels of exhaust emission within limits determined to be acceptable. Regardless of improvements made, however, it is obvious that traffic in the forseeable future will be composed of a mix of vehicles with engines producing varying amounts of air pollution.

IV. RESEARCH PROPOSED - The objectives of this research should be:

1. Perform research to determine the relationship between the geometrical and operational characteristics of various classes of roadways and the level of air pollution emitted from motor vehicles. It is known that the amount of air pollution caused by a motor vehicle is related to the operational characteristics of the facility involved. That is, 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.

2. Evaluate or develop detection devices or systems to measure the amount of pollution a vehicle is emitting at operating speeds.

3. Study the relationship of a city’s altitude, climate and geographical location to air pollution. This may enable planners, weather forecasters, etc. to more accurately predict needs and methods of combating air pollution.

V. PROBLEM ESTIMATE

   Amount Recommended - $300,000
   Contract Term - 2 Years

VI. URGENCY - This is a program designed to narrow an already existing set of functions. This is not considered first priority since the data that will be obtained will probably effect minor alterations to the air pollution situation compared with the drastic changes caused by existing legislation. It is still, however, deemed necessary.
I. PROBLEM NO. 15 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - AIR POLLUTION CRITERIA

III. THE PROBLEM - With the current emphasis on environmental condition, great emphasis has been placed on the impact of air pollution caused by transportation facilities. There is no doubt that the facilities cause air pollution, but there is considerable doubt as to how much pollution is attributable to any given facility, at any particular time, under any given weather condition and ambient air pollution level.

The measurement devices exist, weather data exists and traffic volume data exists, but no real criteria or even guide lines 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 adjacent users of 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 very undesirable from a comfort standpoint, but they are short lived, short ranged and from most reports, non-toxic, yet these are the most undesirable effects. Carbon monoxide on the other hand is odorless, tasteless and lethal. The concentrations necessary to effect health, however, are normally not created on open right of way situations.

IV. RESEARCH PROPOSED - The objectives of this research should be:

Determine air pollution criteria that will satisfy:

1. the driver
2. the adjacent user
3. the general air condition

when a transportation facility is determined necessary. This criteria should approximate the noise level criteria contained in NCHRP Report #117. Further it should give ranges of pollution by type. It should present alternatives rather than a blanket statement that CO levels shall not exceed 35 p.p.m. for an 8 hour period.

V. PROBLEM ESTIMATE

   Amount Recommended - $150,000
   Contract Term - 2 Years

VI. URGENCY - This research is considered to be of secondary priority. The research is necessary to other fields, also. The impact of a transportation facility cannot really be evaluated if the effects of the air pollution are determined by arbitrary criteria rather than medical knowledge.

I. PROBLEM NO. 16 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - NOISE ABATEMENT MATERIALS

III. THE PROBLEM - The highway itself is noiseless, but the highway in use 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 would be through the use of sound absorptive materials to screen noise from drivers and from adjacent owners. 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 adjacent users.

IV. RESEARCH PROPOSED - The objectives of this research should be:

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.

Phase 1. The development of sound control materials is not a new field, but their use under conditions encountered in the highway plant is new. Heretofore, vegetation has been called upon to invoke noise control. It appears from recent tests that the density of planting required for sound control is not physically possible. The development of economic, efficient, and practical noise control materials for use in the highway environment would be worthwhile.

Phase 2. The development of procedures for the use of sound abatement materials in conjunction with the highway plant would follow the development of materials. Undoubtedly some materials would serve as coatings while some would be useful as screens. Concrete and asphalt additives to reduce or eliminate tire noise may be possible.

V. PROBLEM ESTIMATE

Amount Recommended - $250,000
Contract Term - 3 Years

VI. URGENCY - This is a current function and should be researched in the near future. Federal and State regulations call for a thorough evaluation of the impact of noise on a given area and the tools for noise abatement are often non-existent. Noting that there is an adverse impact because of noise does not eliminate that impact.

I. PROBLEM NO. 17 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - INFLUENCE OF MICRO-VERTICAL ALIGNMENT ON VEHICLE CONTROL

III. THE PROBLEM - In dealing with the problem of out-of-control vehicles, particularly on a wet pavement, a number of variables have and are being investigated. The pavement-tire relationship 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 micro-vertical alignment (faulted pavement joints, fill settlement, bridge and culvert settlement, feather-edged surfacing termini, etc.) or irregularities in the pavement surface can and do produce vertical force components in the motion of the vehicle which 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 up to 100% of the static load; zero load on the tires of moving vehicles has been recorded over distances as great as fourteen feet.

References pertaining to this problem:


Engenes, Svein O., A Study of Pavement Strains and Deflections Produced by Dynamic Tire Forces, Joint Highway Research Project No. 21, Purdue University, July, 1969 (73 pages).

IV. RESEARCH PROPOSED - The objective of the research is to measure the joint influence of micro-vertical alignment with horizontal alignment and/or pavement crown on adverse vehicle behavior (incidents and/or accidents) which 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, etc.).

Envisioned is 1) the measurement of weight components against the pavement at many micro-vertical irregularities, 2) collection of accident data at such locations, 3) collection - using photographic means - of vehicle movements at such locations, and 4) correlation analysis of data collected.

V. PROBLEM ESTIMATE

Amount Recommended - $215,000
Contract Term - 1 1/2 Years

VI. URGENCY - Results would be used in determining when pavement maintenance is required and in setting tighter standards for pavement overlays (where they transition with an existing pavement).

I. PROBLEM NO. 18 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - EFFECT OF SHADOWS CAST BY ROADSIDE FEATURES ON TRAFFIC OPERATIONS
III. THE PROBLEM - During the past few years there have been isolated high accident locations on rural high speed highways where accident analysis review teams have concluded that shadows cast on the traveled lanes by roadside features have been a significant factor in the cause of accidents.

There appears to be a reluctance on the part of the motorist 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 traveled lanes; but, a better understanding of driver reaction to various shadow patterns would provide the 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, due to delayed diurnal insolation. The relative importance of this effect as an accident causative factor also needs to be determined.

IV. RESEARCH PROPOSED - The objectives of this research should be:

1. To study the effect shadows cast on road surfaces have on motorists approaching and driving over such shadows.

2. To study the effect shadows have on road surfaces as related to ice formation on surfaces where shadows are cast.

V. PROBLEM ESTIMATE

Amount Recommended - $100,000
Contract Term - 18 Months

VI. URGENCY - This problem is of significant importance to topics of highway environment and accident causation and prevention.

I. PROBLEM NO. 19 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - NOISE POLLUTION

III. THE PROBLEM - What is noise pollution? What effect does transportation 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 fifteen minutes in one state may be reviewed with a job measured for five minutes at 11:00 P.M. in another state and compared with a job using a random spot reading in another state.
IV. RESEARCH PROPOSED - The objectives of this research should be:

Analyse and evaluate the various opportunities and methods for measuring transportation noise and should develop standardized guidelines for same.

V. PROBLEM ESTIMATE

Amount Recommended - $175,000
Contract Term - 2 Years

VI. URGENCY - This research is considered to be second priority. The affects of air pollution are considered to be high priority because they are not as easily detectable and are sometimes lethal. Noise pollution is detectable by the normal person. The more subtle effects, however, must be considered and researched to determine the psychological and physiological effects of noise.

I. PROBLEM NO. 20 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - OPERATIONAL LIMITATIONS ON THE MAXIMUM NUMBER OF FREEWAY LANES IN URBAN AREAS.

III. THE PROBLEM - It has been the practice in highway planning and design in large urban areas generally to limit the maximum number of contiguous through lanes on a freeway roadway to four and to provide for demands exceeding its capacity 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 due either to insufficient capital funding or public opposition to specific urban routes. As a consequence of these delays traffic demands on the existing system of freeways has caused operational saturation requiring such remedial measures as traffic surveillance and ramp metering or the 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, it may become cost-effective to plan, design and construct freeways with greater capacity than that which would be required when a completed system is available. It is conceived that the addition of a lane could produce a twenty or twenty-five percent increase in cost. The addition of a lane(s) may develop to be the required urban transportation strategy over the next 10, 15, or 20 years, applied to a limited number of critical urban routes.

Since very few urban freeways provide more than four contiguous through lanes and little traffic research has been done on those routes which do, it would be in the interest of furthering the understanding of operations on such routes, and of furthering the understanding of urban transportation systems under stress to investigate the operational problems attendant on freeways having more than four lanes on each roadway.
Operational problems on freeways having more than four lanes on each roadway are likely to be related to at least two fundamental parameters; trip length distribution and interchange spacing. As an example of this relationship consider the case in which the mean urban freeway trip length is six miles and interchange spacing is one mile. To achieve a reasonable balance of flow on each of four 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 six mile trip on the freeway. This condition produces six lane changes over the length of the trip or one lane change per mile. While this example simplified 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 eight lane changes would have been required in the six mile distance and resulted in a lane change every 3/4 mile. Since excessive lane changing may adversely affect highway capacity, the significance of the added lane on operational effects may be seen directly.

IV. RESEARCH PROPOSED - The objective of the proposed research should be:

1. To relate freeway traffic operational parameters such as speed, volume, density, lane change frequency and accident experience on specific saturated urban routes having three or four lane roadways to the trip length distribution and interchange spacing for that route.

2. To apply the relationships found for the above routes to actual five lane roadways if any exist or to simulate the effect of a traffic saturated five lane roadway to determine the nature of its operational problems.

Scope: The research should be confined to a limited number of specific urban routes and should be performed intensively to produce significant relationships between the operational parameters, trip length distribution and interchange spacing. Secondary effects such as increased interchange traffic demand and consequent operating problems resulting from increased freeway capacity while important are not included as a part of this research.

V. PROBLEM ESTIMATE

Amount Recommended - $200,000
Contract Term - 2 Years

VI. URGENCY - This problem is of pervading importance in assisting in the development of urban transportation strategies for large urban areas.

I. PROBLEM NO. 21 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - PASSING SIGHT DISTANCE (NO PASSING ZONE SIGNS, MARKINGS, LAWS AND WARRANTS)

III. THE PROBLEM - There has not been, until now, a satisfactory technique for the roadway designer to determine the effect of the percentage of passing sight distances on speeds and level of service on two-lane, two-way rural highways.
Recently, however, a study was completed in the United States which investigated the relationships between the independent variables of percent of the total length of a section of highway marked with no passing barriers and the traffic volume input to the section of highway, 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 relationships were developed employing a calibrated and tested digital computer model. The model is applicable to two-lane, two-way rural sections of highway approximately five miles long, with two-way volumes between 100 and 1,200 VPH, any directional distribution of two-way volumes, any percent of medium trucks (single-unit), any percent of heavy trucks, grades not greater than plus or minus 8 percent and little or no side road traffic volume.

Regression equations and graphs developed for the above variables from the model, together with other data from the referenced study, provide significant insight into the effect of the percentage of passing sight distances on speeds and level of service on two-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 highway users. Present criteria for NO PASSING ZONES in the United States are based on measurements of driver and vehicle performance conducted over 25 years ago and on assumptions which 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 due to inadequate sight distances or other special conditions. These deviations can usually mislead the highway user and subject him unnecessarily to hazard and/or arrest.

The current "Manual on Uniform Traffic Control Devices" indicates that where passing must be prohibited, a no-passing zone shall be marked by either a one direction or two direction pavement marking. Subject to this requirement, the Manual provides various permissive methods for defining a NO PASSING ZONE. These can be summarized as follows:

1. Regulatory pavement markings with no signs.
2. DO NOT PASS sign without any regulatory markings.
3. Regulatory markings with a DO NOT PASS sign.


2. Emergency Indicator: A term indicating that corrective measures had to be taken by a passing vehicle to avoid an accident, including either aborting the passing maneuver, or completing the passing maneuver by using maximum acceleration and speed.

3. Speed-change cycle: A measure of the change in operating speed from one value to another. A full speed change cycle consists of two halves and is a measure of a change in operating speed from and back to an initial speed (e.g., from 50 mph to 30 mph to 50 mph).
(4) Regulatory markings with a NO PASSING ZONE warning sign.
(5) Regulatory markings with DO NOT PASS and NO PASSING ZONE signs.
(6) DO NOT PASS and NO PASSING ZONE signs without any markings.

Methods (2) and (6) 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 users 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 such messages as UNSAFE TO PASS. They also sign and/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 center lines 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 NO PASSING ZONES, signs or markings. Where snow conditions exist over 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.

IV. RESEARCH PROPOSED - The preceding described problem can be attacked in three phases: the first to deal with warrants and criteria for establishing NO PASSING ZONES; the second to deal with the regulatory devices, such as signs and markings, and the third to consider the traffic regulations, enforcement and legal requirements.

IV. RESEARCH PROPOSED

A. Warrants and Criteria for NO PASSING ZONES

Develop a factual basis for the review, validation or modification of warrants and criteria for designating NO PASSING ZONES on two lane, two-way highways and recommend modifications.

The specific objectives and approach are to:

1. Review, evaluate and consolidate past research on passing maneuvers.

2. To the extent that definitive information is not obtained in Step 1, review accident records on existing highways with and without no passing zone markings, and with a variety of geometric and traffic conditions, to determine the magnitude and pattern of accidents involving a passing maneuver and the apparent effectiveness of existing signing and marking practices; with due consideration of prevailing law enforcement practices.
3. To the extent that definitive information is not obtained in Step 1 and to the extent that Step 2 defines situations in which present marking practices are deficient, observe and measure passing practices under a variety of traffic, geometric, signing and marking conditions to determine:

(a) The pattern of passing practices on highways without no passing signs or markings.

(b) The pattern of passing practices on highways with no passing signs or markings.

(c) The acceleration, deceleration and clearances utilized by drivers of various classes of vehicles involved in passing maneuvers under restricted sight distance conditions.

(d) The correlation that must be made between speed zoning and no passing zone control involving the question of adjusting the length of the no passing zone to compensate for raising or lowering the speed limit.

4. Utilizing the findings of Step 3, modify the earlier reference model to predict, for varying combinations of vehicle speeds and geometric conditions, the sight distances required by various classes of vehicles for a safe passing maneuver.

5. Utilizing the modified model developed in Step 4, predict the delays and the accident rates which would be experienced under varying traffic and geometric conditions with no passing zones of varying lengths.

6. Utilizing the findings of Steps 2, 4 and 5, develop a recommendation for improvement of the criteria and warrants for designating no passing zones.

B. Regulatory Traffic Control Devices

Develop comprehensive recommendations and guide lines 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.

The specific objectives are to:

1. Consolidate, organize and evaluate data from previous studies and investigations of no-passing zone controls to determine the justification and need for signs to supplement or replace no passing zone pavement markings.

2. Analyze the standard sign designs and the various sign options to determine desirable improvements or refinements including the feasibility of symbols instead of word messages.
3. Investigate the cost of maintaining signs and/or markings in acceptable condition the year-round, especially in those locations with considerable mountainous or rolling terrain and with seasonal snow conditions.

C. Traffic Regulations, Enforcement and Legal Requirements

Determine the action that must be taken by countries to implement or legalize any regulatory device controlling no passing zones.

The specific objectives are to:

1. Examine the provision of existing Vehicle Codes and laws relating to the establishment and regulation of no-passing zones to assess the problem confronting countries in adopting a uniform regulation. Develop a specimen regulation that would be compatible with the recommended standard for signing and marking the zones.

2. Explore the problem of liability for proper placement and maintenance of no-passing zone signs and markings, especially where sovereign immunity has been waived with regard to road and traffic regulations.

3. Investigate the enforcement problems associated with no-passing zone signs and markings, long and short zone concepts, and advisory versus regulatory control methods.

VI. PROBLEM ESTIMATE

Amount Recommended - $250,000
Contract Term - 3 Years

I. PROBLEM NO. 22 - PRIORITY CATEGORY C

II. NAME OF PROBLEM - SNOW REMOVAL AFFECTED BY MEDIAN TYPE

III. THE PROBLEM - Snow removal has been one of the major jobs of highway maintenance during winter. Several different approaches have been suggested to get this job done. 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 and thrown to the road side by using various kinds of plows. 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 very well on sections with depressed medians, as the melt will flow 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.
IV. RESEARCH PROPOSED - The objectives of this research should be:

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.

V. PROBLEM ESTIMATE

Amount Recommended - $75,000
Contract Term - 1 Year

VI. URGENCY - As the proposed freeway systems will be stretched into the mountain areas, and more freeways are being built in the urban area, more and more raised or flush medians will be constructed. It would be of significant importance to have this proposed research conducted before many mistakes are made.