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RESEARCH PROBLEM STATEMENTS

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22 highway design
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53 traffic control and operations
55 traffic measurements

OPERATION AND MAINTENANCE OF TRANSPORTATION FACILITIES

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INTRODUCTION

Committee A3A08, Operational Effects of Geometrics, has engaged in an activity which its membership believes is one of its several major charges, that of identifying research needs and communicating them to the transportation research community. The committee has previously evaluated and published research problem statements, and the publication of this Circular is a continuation of that activity.

In previous evaluations of research problem statements, the committee has found that a "one-shot" evaluation approach by its membership did not produce particularly clear-cut priority ranking regardless of the basis, i.e. absolute rank or assignment of hypothetical research funds. However, the committee's experience did show that, although individual members ranked research statements differently, there was unanimity among the respondents as to which statements fell in the top 5 and second 5 categories.

As a result of this experience, the committee agreed to use the Delphi technique in its next round of research problem statement evaluations. The Delphi technique utilizes the feed back of opinions of the evaluators and depends on iterations of the evaluation process to produce a convergence of opinion. Other experience with the Delphi technique had suggested that this would be a powerful tool for evaluation.

ANALYSIS METHOD

In utilizing the Delphi technique, the individual committee members were instructed to evaluate each of eight current research problem statements for absolute rank, to allocate hypothetical research funds from a total research budget which was not to be exceeded, to assess the probability of success on a one to one hundred percent basis, and to briefly provide the rationale for each evaluation.

The results were summarized such that anonimity was maintained. Twenty-two committee members were sent the evaluation materials; however, mail problems, changes in professional assignments, and other phenomena produced only twelve respondents. During the course of the second iteration (the third evaluation), the committee held its mid-year meeting in Chicago (July 1977) and conducted an ad hoc evaluation, complete with discussions.

EVALUATION RESULTS

Of the 12 committee members in attendance in Chicago, six had been respondents in the previous mailed evaluations. The effect of the face-to-face discussion in Chicago was to slightly shift the emphasis placed on certain of the research statements. However, one statement emerged early in the mail procedure as well as in the Chicago discussions as being of the highest priority. It held this position throughout all of the evaluations. Two of the statements were found to be presently under study and are not included in this publication. Of the remaining five statements, one was ranked as having a moderate priority and the others as having a low priority.

The following tabulation summarizes the results of the evaluation.

Priority Category	Problem Statement Number	Title
High	1	Synthesis of Safety Research Related to Traffic Controls and Roadway Elements
Moderate	2	Operational Limitations on the Maximum Number of Freeway Lanes in Urban Areas
Low	3	The Effect of Short Climbing Grades on Urban Freeway Operations Under Near Saturated Flow Conditions
Low	4	Energy Consumption Through Truck-Climbing Lanes
Low	5	Vehicle Equivalency and Capacity Including the Effects of Commercial and Recreational Vehicles on Rural Non-Controlled Access Highways
Low	6	Effects of Illumination on Traffic Operations on Non-Controlled Access Roads

PROBLEM NO. 1: SYNTHESIS OF SAFETY RESEARCH RELATED TO TRAFFIC CONTROLS AND ROADWAY ELEMENTS

In 1963, the Automotive Safety Foundation in cooperation with the U. S. Bureau of Public Roads published "Traffic Control and Roadway Elements - Their Relationship to Highway Safety". The report was published in an attempt to foster wider and more uniform application of design features of proven safety value. From 1968 through 1971, the Automotive Safety Foundation with the aid of others updated their 1963 report by publishing a series of 12 chapters which dealt with railroad grade crossings, traffic volume, illumination, intersections, driveways, speed and speed control, cross section and pavement surface, pedestrians, interchanges, one-way streets and parking, general design, and alinement.

Since 1971, there has been a proliferation of roadway element related safety research which deals with the subjects of the aforementioned chapters. For example, during the last five years, the Federally Coordinated Program (FCP) of Research and Development for Highway Transportation has contained research projects which have dealt with improved geometric design, skid accident reduction, railroad grade crossing safety and safety of pedestrians and abutting property occupants. Several research publications have resulted from these FCP projects and from other safety research. The abundance of post 1971 technical safety research reports and papers presents a wealth of findings that need to be synthesized for use by decision makers dealing with traffic control and roadway elements.

Reports such as the second edition of "Highway Design and Operational Practices Related to Highway Safety" (1974), the revised 1973 "Handbook of Highway Safety Design and Operating Practices" (being revised again now), and "Geometric Design Guide for Resurfacing, Restoration, and Rehabilitation (R-R-R) of Highways and Streets" (1977) have been published since 1971. However, these reports do not specify policy nor is there

much research cited to support the "ideas" and "guidelines" presented for improving safety design and operating practices.

RESEARCH PROPOSED

The objectives of the proposed research should be to:

1. Update the series of publications issued by the Automotive Safety Foundation between 1968-1971 which dealt with the relationship of traffic control and roadway elements to highway safety.

2. Add three new chapters to the series to deal with 1) work zone (construction and maintenance) safety, 2) bicycle lanes, and 3) priority lanes.

Both United States and foreign research results should be considered in meeting these objectives. Post 1971 research results should be given heavy emphasis in the synthesis. In providing the updated synthesis, strong consideration should be given to including cost information related to achieving safety through the various traffic control and roadway elements (see NCHRP 3-25 reports on "Cost and Safety Effectiveness of Highway Design Elements").

It is also suggested that the format of chapters which deal with subjects pertaining to stretches of roadway (e.g., cross sections, speed and speed control, alinement, etc.) be modified to present research findings by type of facility such as freeways, four-lane undivided highways, two-lane rural highways, urban arterials and low volume (less than 400 ADT) rural roadways.

The synthesis must be sufficiently brief to permit decision makers to absorb and make effective use of the multitude of new research results.

The chapter on Railroad Grade Crossings should be broadened to include findings regarding the safety effectiveness of new railroad protective devices. More attention should also be given to the traffic composition portion of the chapter on Traffic Volume since the U. S. vehicle population (low-powered automobiles, recreational vehicles and larger trucks) is changing significantly.

PROBLEM ESTIMATE

Amount Recommended - $100,000
Contract Term - 1 year

URGENCY

An updated synthesis of safety research related to traffic control and roadway elements is needed because of 1) a changing emphasis from construction of freeways to resurfacing, restoration, and rehabilitation of other major traffic carrying facilities, 2) the shrinking value of available highway dollars, 3) more demands for highway transportation dollars, 4) increased concern for improving safety in construction and maintenance work zones, 5) expressed concern by some to reduce design standards for highways, 6) questions regarding the design and operation of low volume roads, 7) changing speed patterns as a result of the national 55 mph speed limit, and 8) possible traffic operational problems created by an emerging new mix of traffic, i.e., more small low-powered automobiles, larger trucks and a greater number of recreational type vehicles. All of the listed factors can affect decisions made relative to control of traffic and highway design which, in turn, can affect highway safety. Accordingly, decision makers need in an abbreviated form the latest research results emanating from traffic control/road element/safety research.

PROBLEM NO. 2: OPERATIONAL LIMITATIONS ON THE MAXIMUM NUMBER OF FREEWAY LANES IN URBAN AREAS

It has generally been the practice in highway planning and design in large urban areas to limit the maximum number of contiguous through lanes on a freeway roadway to four, and to provide for demand exceeding this 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 a continuous shoulder to a traffic lane. 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 capacity for much less than a twenty-five percent increase in cost. On a limited number of critical urban routes, the addition of lanes may be the required urban transportation strategy over the next 10 to 20 years.

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 urban transportation systems under stress to investigate the operational problems associated with freeways having more than four lanes in each direction of flow.

One authority suggests that "The standard maximum number of lanes per roadway (same direction) is four, although some sections of five and six lane roadways have been built in special circumstances. Where more than four lanes in one direction are needed, a third (reversible) or two additional roadways are provided." (See N. Kennedy, J.H.Kell, and W. S. Homburger. Fundamentals of Traffic Engineering—8th Ed., Institute of Transportation and Traffic Engineering, University of California, Berkeley, 1973.)

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 the 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 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 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.

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 freeways having three or four lanes in one direction to the trip length distribution and interchange spacing for that route..

2. To apply the relationships found in 1. to actual five lane roadways, or to stimulate the operation 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.

This research should include new freeways or existing freeways with four or more twelve foot lanes in one direction and existing freeways where an additional lane has been formed by reducing lane widths and/or utilizing a continuous shoulder.

PROBLEM ESTIMATE

Amount Recommended - $150,000
Contract Term - 1 1/2 years

URGENCY

This problem is of critical and pervading importance in assisting in the development of urban transportation strategies for large urban areas.

PROBLEM NO. 3: THE EFFECT OF SHORT CLIMBING GRADES ON URBAN FREEWAY OPERATIONS UNDER NEAR SATURATED FLOW CONDITIONS

Urban freeways carrying mixed traffic under near-capacity conditions for level sections experience speed reductions with the introduction of short climbing grades as typified by changes from a depressed to elevated condition. In certain cases, the reduction in speed below a critical level produces 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 on every working day.

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.

While much research has been performed on vehicle climbing characteristics and the relationship of road profile to capacity, this work has largely been oriented towards more rural conditions and has tended to concentrate on large differences in elevation and on relatively long climbing distances.

RESEARCH PROPOSED

Develop the relationships between such parameters as vehicle mix, speed changes, capacity, grade and vehicle operating characteristics for climbing roadways under 3,000 ft. in length and with elevation differentials less than 75 ft. on saturated urban freeways in large metropolitan areas. Research is needed to:

1. Structure data collection into groupings of observations of at least the above parameters for varying classifications of grade, elevation differentials and climbing lengths under conditions of saturated or near saturated flow.

2. Analyze the operational effects of grade, elevation differentials and climbing lengths for the varying classifications.

3. Develop the relationships among the various parameters studied.

4. Postulate guidelines for the design of urban freeway sections requiring changes in elevation where saturated flows are anticipated.

PROBLEM ESTIMATE

Amount Recommended - $200,000
Contract Term - 1 1/2 years

URGENCY

This problem is of importance where new freeways are to be constructed. A system's view of a roadway profile is needed to insure that bottlenecks and potentially hazardous situations are not being designed into the highway system because of the failure of a designer to appropriately consider vehicle mix and vehicle operating characteristics. As the use of larger commercial vehicles, recreational type vehicles, and low powered automobiles increases, the problem becomes more prevalent.

PROBLEM NO. 4: ENERGY CONSUMPTION THROUGH TRUCK CLIMBING LANES

For many years highway engineers have been concerned with reduction of traffic delay. They have developed and utilized computerized traffic signal systems and freeway control systems. Improved design characteristics have also been introduced, including priority lanes and bypass lanes on freeway entrance ramps. Further, many older design standards such as the one pertaining to the need for truck climbing lanes have also been based to a great extent on delay.

Slow vehicles ascending grades not only subject trailing vehicles to delay, but also create a potential hazard to faster moving overtaking vehicles. This safety problem is now being addressed in the FCP on Rural Two-Lane Highways wherein both passive and dynamic signing to warn drivers of slow moving vehicles on grades will be evaluated. Also in the FCP, another study is being

designed to establish the influence of various types of trucks and recreational vehicles on traffic flow over rural noncontrolled access highways. Grade steepness and grade length are some of the independent variables that will be considered in the study.

Results from these two studies will, no doubt, provide useful information that can be utilized by highway engineers in improving warrants for application of truck climbing lanes. Still, one important factor is not being considered in the two studies as now defined, namely, energy consumption. This is at least partially due to the fact that refined relationships between energy consumption and road geometrics have not been established. Although the Environmental Protection Agency (EPA) and the Urban Mass Transportation Administration (UMTA) are now planning programs to develop equipment for use in several hundred vehicles to develop these more refined relationships, current practice should already be employing existing energy consumption-speed relationships to improve existing design warrants. Accordingly, the following research on improving warrants for truck climbing lanes is proposed.

PROPOSED RESEARCH

The objectives of this research should be to:

1. Define the energy consumption-speed relationships to be employed for vehicles to update truck climbing lane warrants; i.e., what traffic volumes, classes of vehicles, speed measurements, and roadway geometric combinations need to be considered?

2. Assemble existing information in the literature to develop such relationships.

3. Develop a methodology for using the existing energy-speed data in combination with existing safety and delay measures of effectiveness (MOE's), i.e., how should the various MOE's with different units be weighted and combined in analyzing the need for truck climbing lanes?

4. Use the methodology developed in 3. to prepare new truck climbing lane warrants which may , because of the several variables, be in the form of nomographs or tables.

5. Prepare an abbreviated handbook which describes the new warrants and shows by example how practicing highway engineers should make use of them in determining whether or not a truck climbing lane is needed.

Scope: This research should result in warrants for bidirectional two-lane roadways and freeways. It should also describe the additional data which should be collected by EPA and/or UMTA utilizing the equipment they are now planning to develop, i.e., under what combination of traffic, geometric, and speed flow conditions is there need for more energy consumption data? It is not envisioned that this research would involve any field work.

PROBLEM ESTIMATE

Amount Recommended - $100,000
Contract Term - 1 year

URGENCY

This problem is important. It addresses the problem of energy consumption with regard to one major road geometric feature. Further, when the research is completed, a methodology for combining delay, safety, and energy consumption MOE's should be available for use in examining other design warrants and operational procedures; e.g., when to provide grade separations, open draw bridges, build construction detour lanes, etc. The research should also be very helpful in making effective use of EPA's and UMTA's planned data collection equipment.

PROBLEM NO. 5: VEHICLE EQUIVALENCY AND CAPACITY INCLUDING EFFECTS OF COMMERCIAL AND RECREATIONAL VEHICLES ON RURAL NONCONTROLLED ACCESS HIGHWAYS

Among currently identifiable factors influencing highway capacity and levels of service, probably less is known about the influence of trucks and buses than any other factor. Current criteria, both in the 1965 Highway Capacity Manual and the 1965 AASHO (now AASHTO) Policy on Geometric Design of Rural Highways (Blue Book), are open to serious question not only on an absolute accuracy basis, but also on a relative basis. Further, no adequately validated criteria are yet available regarding the influence of recreational vehicles such as campers, house trailers, and mobile homes which are a rapidly increasing proportion of the total traffic volume in and enroute to recreation areas.

Highway planners, designers, and operators are, therefore, in need of better information on the effects of trucks of various sizes and types, buses, campers, and passenger cars with trailers on traffic flow on level ground and on grades on two-lane and multi-lane highways.

PROPOSED RESEARCH

The objective of this research should be to establish the influence of various types of trucks, buses, and recreational vehicles on traffic flow over rural noncontrolled access highways. The measure of influence should be passenger car equivalents unless some other measure is found more appropriate.

The research should provide results which establish factors for expressing the influence on traffic flow of varying percentages of motor vehicles of various types, including passenger cars, buses, trucks, and recreational vehicles. These factors should be developed with regard to rural two-lane and multi-lane highways where access is not controlled and for a wide range of traffic volumes and vehicle classifications.

Among the independent variables which should be considered are speed and related all-passenger-car volumes, percentage of each vehicle type other than pure passenger cars (buses, single-unit trucks, tractor-trailers, pick-ups with campers, passenger cars with utility trailers, passenger cars with house trailers, mobile homes, etc.) grade steepness, grade length, and roadway geometrics.

The research should be performed to provide an update, refinement, and expansion of the truck equivalency tables for two- and four-lane rural highways appearing in Chapter 10 of the 1965 Highway Capacity Manual. This includes the expansion of the tables to include the effect of trucks of various types. In addition, the research output should include, where applicable, additions to the tables to include the effect of various types of recreational vehicles.

Specific questions that should be answered through this research include the following:

1. Is the "vehicle equivalency" concept the most effective way of representing the relative influence of vehicle types other than passenger cars? If not, provide an alternative concept which would be superior.

2. Can the concept adequately represent groups of a particular category of vehicles (for instance, a queue of several trucks) as well as individual vehicles?

3. Do the procedures described in the following recent reports appear valid based upon applications to highway and vehicle types to be studied in this research?

   a. Work of Midwest Research Institute on NCHRP Project 3-19 "Grade Effects on Traffic Flow Stability and Capacity."

   b. Alexander Werner in his paper "Effects of Recreational Vehicles on Highway Capacity."

   c. Applicable sections of Midwest Research Institute FHWA Contract FH-11-7739 "Freeway Design and Control Strategies Affected by Trucks."

PROBLEM ESTIMATE

Amount Recommended - $500,000
Contract Term - 2 1/2 years

URGENCY

It is doubtful that this research can be completed in time for the current updating of the Highway Capacity Manual. However, with the increasing usage of large commercial vehicles and recreational type vehicles, this research needs to be performed to be available for subsequent HCM revisions.

PROBLEM NO. 6: EFFECTS OF ILLUMINATION ON TRAFFIC OPERATIONS ON NONCONTROLLED ACCESS ROADS

Nighttime highway accident rates tend to be significantly greater than daytime rates and noncontrolled access 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 severe accidents than those which are not so lighted. Many factors have been shown to affect the nighttime 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 nighttime lighting conditions to daylight shows that 1) the absence of street lighting produces twice the accident experience; 2) "poor" street lighting produces eighty percent higher accident experience; 3) "average" street lighting produces sixty percent higher accident experience; and 4) "good" street lighting produces thirty percent higher accident experience. 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.

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 noncontrolled access roads relating highway lighting to driver-vehicle performance while isolating and controlling such environmental variables as roadway reflectance and geometry.

PROPOSED RESEARCH

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 noncontrolled access roads. Varying visual acuity and behavioral traits in the driving population should be accounted for, but are not the immediate subject 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 variables affecting the nighttime driving tasks and consequent vehicular behavior.

PROBLEM ESTIMATE

Amount Recommended - $150,000
Contract Term - 1 1/2 years

URGENCY

This problem is of pervading importance in improving nighttime safety and operating performance of roads through the application of increased understanding of the factors affecting roadway illumination and consequent driver-vehicle performance.