NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT **55**

RESEARCH NEEDS IN HIGHWAY TRANSPORTATION

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

HIGHWAY RESEARCH BOARD 1968

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BERTRAM D. TALLAMY ASSOCIATES
WASHINGTON, D. C.
AND
WILBUR SMITH AND ASSOCIATES
NEW HAVEN, CONN.

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS IN COOPERATION WITH THE BUREAU OF PUBLIC ROADS

SUBJECT CLASSIFICATION
ALL SUBJECT AREAS

HIGHWAY RESEARCH BOARD
DIVISION OF ENGINEERING NATIONAL RESEARCH COUNCIL
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Bureau of Public Roads, United States Department of Transportation.

The Highway Research Board of the National Academy of Sciences-National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway departments and by committees of AASHO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Highway Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

This report is one of a series of reports issued from a continuing research program conducted under a three-way agreement entered into in June 1962 by and among the National Academy of Sciences-National Research Council, the American Association of State Highway Officials, and the U. S. Bureau of Public Roads. Individual fiscal agreements are executed annually by the Academy-Research Council, the Bureau of Public Roads, and participating state highway departments, members of the American Association of State Highway Officials.

This report was prepared by the contracting research agency. It has been reviewed by the appropriate Advisory Panel for clarity, documentation, and fulfillment of the contract. It has been accepted by the Highway Research Board and published in the interest of an effectual dissemination of findings and their application in the formulation of policies, procedures, and practices in the subject problem area.

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FOREWORD

By Staff

Highway Research Board

This report has been specifically prepared for and tailored to the needs of top highway officials, research administrators, and researchers, to aid them in formulating a meaningful highway transportation research program. Transportation systems and related research needs, meeting recognized national transportation research goals, are discussed. A framework or concept of structuring a research program is developed with a method of assigning priorities and funding requirements to proposed research projects.

Highway transportation research efforts resulting from existing program procedures frequently appear somewhat fragmented and not part of overall objectives. There has been no mechanism available to insure coordination or balance among the areas of greatest need. Although it is essential that final formulation of each research program remain the prerogative of highway officials, the best interest of the States can be served by a coordinated long-range, comprehensive program of research needs developed to serve as a framework for all future highway research.

In this report the consultant partnership of Bertram D. Tallamy Associates and Wilbur Smith & Associates presents the results of extensive studies on developing a system for the structuring and regular updating of research programs. Development of highway research in this country is described, the various research agencies are identified, and findings from the search of existing literature on highway research needs are discussed. The consultants present a systematized procedure and structure through which the entire effort by highway agencies may be managed and coordinated with continuity and clarity toward defined goals. Additionally the problem of funding is discussed and a method of assigning priorities to research projects is presented. To illustrate the structuring and priority assignment techniques, an appendix presents a sample program that draws on an unrefined pool of more than 900 suggested research projects.

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SUMMARY

The growing complexity of our ever-developing highway transportation system offers almost limitless challenges to the researcher. At the same time, the unsatisfied demands for more highway transportation facilities and the limited funds from which to meet these demands make the optimum allocation and assignment of research funds an equally difficult task for the highway administrator.

In an attempt to respond to the concern of both administrator and researcher over the fragmented and oftentimes uncorrelated research effort that has been made in the past in highway transportation, this report has been prepared.

Essentially, National Cooperative Highway Research Program (NCHRP) Project 20-2 and this resultant report have done three things:

First, a method or concept for structuring research has been developed;

Second, a method for assigning priorities and costs to proposed research has been developed; and

Third, the methods have been applied to 900 proposed research project statements considered in the study and an example research program has been produced.

Structure Concepts

The establishment of a meaningful research structure first requires the setting of overall goals or objectives. Identification of major national transportation research goals can then be followed by the identification of subordinate, compatible goals for highway transportation research. The major goals of highway transportation research, which should reflect the long-range direction of effort, will warrant review and restatement only infrequently if the resultant program is to maintain continuity.

Under each of these highway transportation goals, broad researchable problem areas currently affecting attainment of these goals can be identified. Inasmuch as these broad-based problem areas will be responsive to specific immediate concerns, policies, and other current influences, they should be reviewed regularly and updated as required. At the same time they can be assigned a relative priority value (3 high, 2 intermediate, 1 low) by the selection committee.

As the basic source from which the research structure is created, this concept requires (1) the continuing replenishment of a stockpile of specific proposed research projects, and (2) the establishment of a means of coding or classifying and processing these projects in the context of their applicability to the goals and problem areas in the research structure.

The input of proposed research projects for this stockpile can and should continue to flow from all responsible, qualified sources, including the American Association of State Highway Officials (AASHO), the Highway Research Board (HRB), and industry representatives and committees

For coding and stockpiling proposed research projects, the current, ongoing system of the Highway Research Information Service (HRIS) can be used. Inasmuch as HRIS is effectively handling information on research projects that are

completed or in progress, the addition of a record of proposed research is a natural extension of the capabilities of that system.

If the projects have not already been priced, cost estimates should be assigned at this time. For this study, costs were predicated upon an estimate of the man-months of professional effort required. Each man-month was valued at $3,000 and a fixed initiation cost of $25,000 (based on a detailed cost analysis of prior NCHRP research projects) was added to each project.

With a stockpile of projects properly coded under HRIS, as a first step in project selection it becomes a mechanical process to filter out of the stockpile those projects having applicability to a specific problem area. Under an operating system, this could be done through the use of HRIS codes assigned to the problem area by the HRB staff.

The second step in the project selection would be a judgmental evaluation of the worthiness or appropriateness of the project for that particular problem area. It is envisioned that this also would be a staff function utilizing personnel knowledgeable in the particular problem area. At this point also, determinations would be made of the need for modification of proposed projects, combination or subdivision of projects, and the return of inappropriate projects to the stockpile.

As a third step the selected projects would be assigned a priority value (3 high, 2 intermediate, and 1 low) based on the relative importance of the project to the problem area. This could be done through the composite judgment of several qualified members.

Inasmuch as each problem area would carry a priority value and each proposed project would have a priority value within the problem area, it would be possible to construct a composite priority value for each project. A suggested method would first multiply the project priority value by the problem area priority value to produce a product which could be called a weighted priority value. Many projects may appear in more than one problem area and where this is the case the several weighted values for that project would be added together to give the composite priority value for the project.

Illustrative Program Development

With a stockpile of 700 proposed research projects from HRB files and an additional 200 proposed projects developed during this study, the structuring concepts outlined in the foregoing were applied to develop an illustrative program (see Appendix D).

In order to select meaningful goals and problem areas, interviews were held with many highway administrators, researchers, professional societies, and industries. A special two-day symposium was conducted with the principal highway research talent of the nation represented. Frequent staff conferences and analyses were conducted. On the basis of these sources and the foregoing study effort, three national transportation goals were identified, as follows:

1. To serve national commerce and defense by optimizing the development and function of an integrated national transportation system.

2. To improve national, regional, and community development through development of optimum transportation service and integration of transportation facilities with the community.

3. To foster national health and welfare as affected by transportation through (a) increased safety and convenience, (b) reduction of air and water pollution,

and noise abatement, and (c) improved well-being of users and nonusers of transport facilities.

As a subsequent step in developing the structure for highway transportation, research objectives specifically applicable to highway transportation but derived from and compatible with the national transportation goals were identified. These include the following:

1. To improve highway planning, design, and construction as a part of an integrated transportation system.
2. To improve the role of highway transportation in optimizing land use and urban development by improving the safety, serviceability, and operations of the present highway system.
3. To foster the integration of the highway with the community through improved identification and quantification of sociological, political, economic, and aesthetic factors in highway transportation.

Under each of these highway transportation goals, 13 specific problem areas were identified in which knowledge and technological gaps currently prevent full attainment of these goals. There were five problem areas identified under goal No. 1, five under goal No. 2, and three under goal No. 3.

Finally, to flesh out this skeleton or framework of research, *and for illustrative purposes only,* the 900-project stockpile was searched, using the HRIS coding as previously discussed, to identify those projects specifically applicable to one of the 13 problem areas. The selected projects were then assigned a priority value within each problem area and a composite priority value produced to reflect the relative value of each project within the total research structure. In summarizing the results of this development, the composite priority values ranged from a low of 1 to a high of 20. It was interesting to note that in the 253-project, $24-million program which resulted, only 19 projects, totaling $2,194,000 had a priority value above 10. This served to emphasize the broad, multi-project base on which most of the major problem solutions must be built.

In summary, the structuring concept is predicated first on the building of a framework of national transportation goals, compatible highway transportation goals, and major problem areas within each of these goals. These components, selected at the policy-making level in the research organization, establish the basic framework for the research program. The structure then can be filled out, as a staff function, utilizing a continuously replenished stockpile of research projects and a screening process implemented by HRIS coding and classification. A coordinated staff process would be the assignment of composite priority ratings and listings.

The final step in implementing the program would be a process of selection of projects chosen from within the context of the total research structure and with knowledge of priorities and costs in hand. This final step should be exercised at the policy-making level of the research agency. Thus the structuring concept permits policy-level control both in the establishment of the basic character of the research structure and in the ultimate selection of the specific projects to be undertaken as a part of any on-going program.

More complete details on the structuring process and on the results of the application of the process to the unrefined 900-project stockpile are presented in this final report and its appendices.

CHAPTER ONE

INTRODUCTION

Research has been needed in the highway transportation field almost from the beginning of the automobile age. The Federal-Aid Act of 1916 was instrumental in fostering highway construction in the various States and in establishing highway departments to carry on that function throughout the nation. From the outset, the officials of highway departments were concerned about the shortcomings of existing knowledge about road building and transportation by roads. The many uncertainties of how to plan, design, and build highways led the highway administrators into early meetings for informal inquiries and discussions. Later, meetings on research became formal sessions organized under the auspices of the state highway departments as the Highway Research Board (HRB), an arm of the National Research Council of the National Academy of Sciences—National Academy of Engineering. Other agencies, such as the U. S. Bureau of Public Roads, also commenced highway research programs.

In 1919, a paper presented at the annual meeting of the American Association of State Highway Officials (AASHO) suggested a national program of highway research. Dean Anson L. Marston, of Iowa State College, said: "There is a very urgent need for the immediate inauguration of scientific highway research in accordance with a comprehensive national program. The country is about to spend untold billions of dollars in the building of paved roads, yet there is very serious lack of the fundamental scientific data which are absolutely essential to the correct design and construction of those roads." (*1*)

DEFINITION OF RESEARCH

The dictionary (*2*) definition of research is "1: careful or diligent search, 2: studious inquiry or examination; esp: investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws." In general, there are three types of research, as follows:

1. With some liberty, those engaged in *basic research* usually work with simplified and well-defined systems. This certainly does not mean that these systems are simple to describe, synthesize, investigate, and/or analyze, but does imply that they have been constrained in objective. Those constraints may limit the direct applicability of the research results. In no way can this be considered a criticism of such research, from which fundamental discoveries of major significance most often stem. Such basic research seeks what may be called absolute knowledge, in that the results are interpreted primarily in terms of the phenomenology of the system and the research is only secondarily concerned with applications.

2. Those engaged in *applied research,* again with some liberty, may be said to work with those systems that are subject to real-life variables. Rarely is it possible to include all variables, whether they have major or minor effects, in a single study. Therefore, such research may be conducted, on and off, over relatively long periods of time by a number of investigators. This type of research is concerned with relative knowledge in that it seeks to confirm, deny, or modify the phenomenological description of the system. Should no such description exist, applied research concerns itself almost exclusively with the interpretation of the research results from the standpoint of deducing the effect of a particular variable, or set of variables, on the relative behavior of the system in real life. Applied research is most often conducted on parts of systems, or on total systems, in order to emphasize cause and effect or to limit expense.

3. In some instances, a third kind of research may be identified and arbitrarily termed *prototype research* or product development. Here, the system may well be in actual use and only a single dependent variable is of concern. The research may have the nature of proof testing by seeking to improve the system response through innovation or through comparison of alternative effects. Such studies often have the limitation that local or environmental factors prevent direct applicability of the results to similar systems. Prototype research may also involve the construction of a complete system for the purpose of proof testing or for the comparison of a number of variables. Prototypes, although often desirable, are usually quite expensive, and the results derived from this testing may be difficult to interpret and apply because of limited knowledge concerning the effects of interacting variables and also because of local and environmental factors.

That there is overlap between these three arbitrary divisions of research is obvious. Indeed, there would be little technological progress without such overlap. Unfortunately, in many areas the research efforts of many talented people are uncoordinated, leading to an abundance of effort in some parts of certain whole systems and virtually none in others.

Many specific examples could be cited to demonstrate interaction, or the lack of it, between basic, applied, and prototype research. In the vast field of concrete technology, for example, *basic research* has revealed the general form and structure of the hydrates in cement paste and of the paste itself. This has led to a general understanding of the phenomenology of the freezing of water in the paste and the necessity for air-entrainment in concrete subject to freezing and thawing. *Applied research* has extended the number of variables to include durability studies of concrete subject to, for instance, salt solutions and different cement-aggregate systems. The responses indicate additional, and as yet unexplained, complications in the durability of such sysems. *Prototype research* indicates a variation in response in different parts of structures. A significant number of remedies have been attempted to check the deterioration of structural concrete. Despite attempts to coordinate some of these efforts, little direct correlation is possible because of differences in the techniques and aims of the investigators.

Although many agencies combine research and development in a single department or branch, the functions are quite different. In the current study, and in this report, the term "research" has been reserved for the investigative phases which, it is hoped, will yield solutions to problems or lead to better ways of performing an operation. The "development" term should be reserved for the actual building of prototypes or final products, experimentation with manufacturing processes, and, perhaps, development of uses for a newer product or machine. Although both of these operations are often performed in the laboratory and involve the use of testing machinery and equipment, the distinction should be preserved. A distinction also can be made between research and administrative studies or investigations to gather facts for decision making. Although such studies may be necessary for effective administration and transportation systems, they may or may not be appropriate as a part of a "research" program.

Another classification system divides research, and particularly highway research, into "hard" and "soft" areas. Hard research is in the realm of the physical scientist and engineer working on materials, hardware, and structures, and on construction, maintenance, and operation techniques, whereas soft research is in the realm of the traffic engineer, the social scientist, and the economist, working on traffic flow, traffic operation, social impact, economic impact, and land use. History indicates that hard research predominates in nations during the development stage of highway transportation systems and gives way to soft research after the systems have become sophisticated.

NEED FOR STUDY

Many agencies, universities, highway departments, trade associations, and professional societies have devoted considerable effort and funds to research connected with highway transportation. Yet the need continues to be great.*

* When President Johnson signed the legislation creating the Department of Transportation, in October 1966, he said:

"Our system of transportation is the greatest in the world. But we must face facts—it is no longer adequate.

"During the next two decades, the demand for transportation in this country will double But we are already falling behind. Our lifeline is tangled

"We are confronted by traffic jams, by commuter crises, by crowded airports, and crowded airlines, screeching airplanes, archaic equipment, safety abuses, and roads that scar our nation's beauty.

"We meet today to establish a Department of Transportation. It will be a mammoth task to untangle, to coordinate, and to build a national transportation system.

"Among the many duties that the new Department of Transportation will have, several deserve special notice These include:

"To improve safety in every means of transportation, our automobiles, our trains, our planes, and our ships.

"To bring new technology to every mode of transportation by supporting and promoting research and development.

"To solve our most pressing transportation problems."

Despite years of effort, many fundamental questions and problems of highway technology still need better answers and solutions. Along with the growing need for research, there is a parallel need for organization, correlation, and direction of the research effort. It is this latter need to which this study addresses itself.

Although much highway research is in progress, with the many agencies involved there has been a problem of fragmentation and lack of coordination. More than 3,000 highway research projects currently are being performed by several hundred agencies (*3*).

Many projects are in closely related areas, and there may be duplication of effort. Certainly there is some inefficiency in the prosecution of many small projects, because it is difficult for each investigator to have full knowledge of kindred research going on simultaneously.

PURPOSE OF STUDY

The study had as its primary purpose the development of a coordinated, long-range, comprehensive program of research needs to serve as a framework for all highway research in which the States participate. As outlined in the research project statement prepared for this study by the Highway Research Board, the two objectives were:

1. To develop a coordinated framework of needed short- and long-range research in the field of highway transportation.

2. To identify major areas of needed research and arrange these areas in the general framework along which future research could be organized. This is to include an indication of technical priorities of need and an estimate of the appropriate levels of funding for each area. The framework is to be formulated in such a manner as to permit updating with minimum effort.

STUDY PLAN AND PROCEDURES

The plan for the research study included as basic undertakings the development of information from, (1) a review of existing published materials, including HRB project statements; (2) interviews with executives, officials, and technicians of the highway and transportation fields; and (3) a conference of research personnel and administrators representing the various disciplines and agencies, both public and private, concerned with highway research. Survey forms are shown in Appendix E. Figure 1 is a flow chart of the work plan.

Literature Search

Research agency staff members conducted a review of pertinent literature in public, university, agency, and the firms' libraries. Information published and furnished by the HRB and the U. S. Bureau of Public Roads was particularly valuable. For each volume or tract, a brief resume or digest was made of the subject matter, with notes pertaining to possible use of the material in the research study.

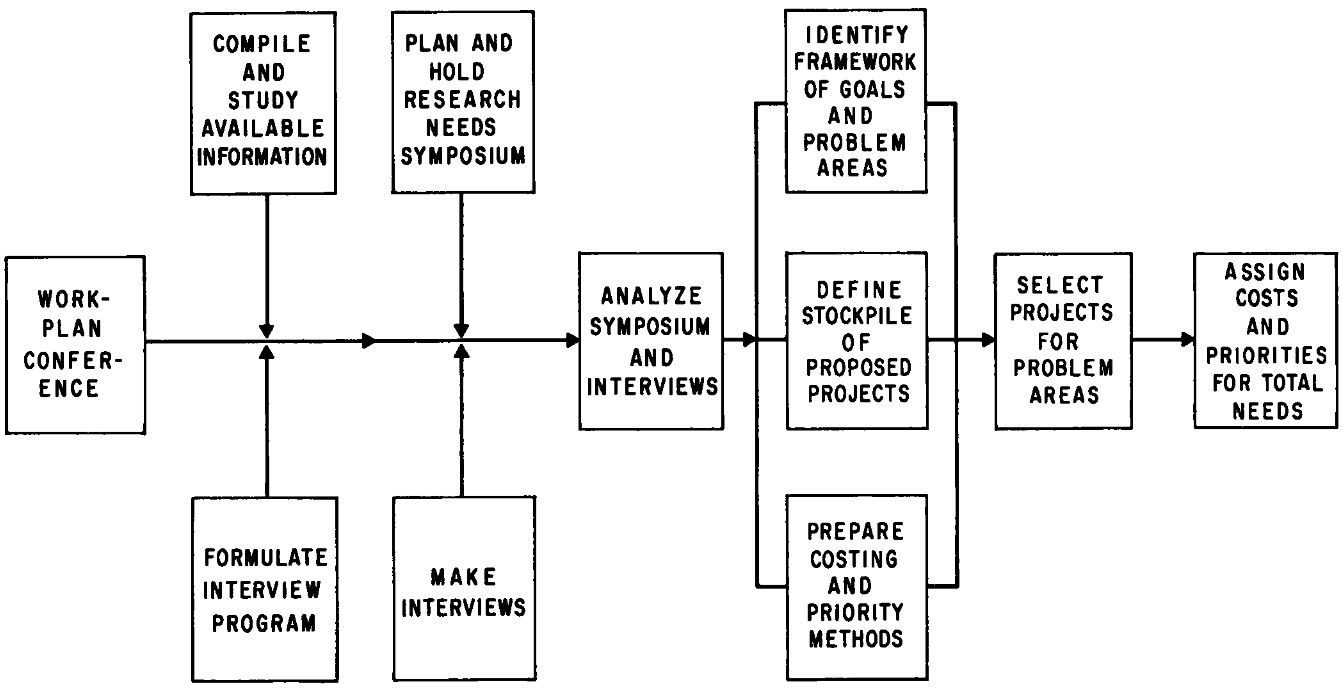

Figure 1. Project work flow.

Project Statements

In this study, project statements which had been collected and developed by the HRB through its departments and committees were examined. As a part of the review by the project staff, one- or two-sentence summaries of the project statements were developed and the projects were classified by general subject area.

The subject area code used was that developed by the HRIS, as given in Appendix C. The use of HRIS subject areas simplified comparison of the research project statements currently proposed by committee chairmen with the research actually under way and recorded in *Highway Research in Progress* (*3*). Although there are many ways to categorize, classify, or file research projects, the HRIS system was selected because it is already developed and well known to highway researchers. No doubt this classification system will evolve and change with time and with improvements in the field of information storage and retrieval.

Personal Interviews

The working plan for the study of highway transportation research needs also involved interviews with leaders in government, industry, and educational fields to obtain their views on national research goals and problem areas relating to highway transportation. In this program, the executive officers or administrators of highway research efforts of some 50 organizations were visited in their offices or laboratories. About 150 interviews were conducted and reports were prepared covering the interviewee's reactions to a list of topics which were of concern to the study.

A wide variety of opinions on objectives, needs, priorities, and funding for a sound highway transportation research program were obtained. Knowledge of existing research structures and programs was sought; ideas for improvement and completely new approaches to research were discussed. Opinions were sought on how to relate or evaluate economic and social benefits from research accomplishments and on ways of estimating the time needed to accomplish specific projects. The interviewers also sought ideas and suggestions on ways to improve dissemination and implementation of research findings. A summary of the interview survey is given in Table 1.

Saratoga Symposium

At Saratoga Springs, N. Y., on Oct. 23-25, 1966, 44 representatives of the many organizations and disciplines interested in highway transportation research were assembled for a conference on national needs for highway transportation research (Table 1). Participants in the conference (see Appendix A) were selected to give the widest possible perspective to the questions involved. Three panel discussions were concerned with:

1. Defining objectives and approaches to highway transportation research.
2. Delineating areas of present and future needs.
3. Assigning priorities, costs, and responsibilities for execution of needed research.

The conference provoked lively discussions and brought forth excellent examples of research accomplishments.

Many new research areas were suggested, as discussed in Chapter Four.

Staff Conferences

The joint study staff held frequent discussions throughout the course of the study. These conferences were concerned with the manner of structuring the various problem areas for research and establishing the goals required to enlist greater support for the required research program.

In addition to the study staff, other members of both firms responsible for the project participated in the conferences and thereby contributed to the work. Every attempt was made to fully utilize the total experiences and resources of the project contractors. In addition, the NCHRP advisory committee for this project met with the principals and staff of the study team several times during the course of the work and frequent conferences were held with the program director of the NCHRP.

Oral reports covering the general findings and recommendations of the study were presented to the Project Advisory Committee and the Research Activities Committee of AASHO in joint session at the Wichita, Kans., meeting of the American Association of State Highway Officials, December 2, 1966, and again at the AASHO meeting in Salt Lake City, Utah, on October 20, 1967.

In the foregoing sections of this chapter the need for organizing and structuring the research effort has been outlined and the method of attack employed by the project staff was discussed. The following chapters discuss: total transportation systems and related research needs; the history of highway research; indicated highway research requirements; a recommended framework for highway transportation research; research costs and priorities; and, finally, the specific application of this structure in the development of an annual highway research program and indicated research needs, as responsive to the original project statement.

TABLE 1

PARTICIPANTS IN INTERVIEW SURVEY AND SYMPOSIUM

	INTERVIEWS [a]		SYMPOSIUM [b]
AGENCY TYPE	AGENCIES	PERSONS	PARTIC.
State highway departments and state agencies	17	54	4
Universities	9	20	6
Federal government agencies	7	21	6
Trade associations and industries	9	26	9
Professional associations	5	11	4
Municipal or regional governments or authorities	8	11	2
Foreign and other	4	7	—
Foundations and institutes	—	—	2
Consultants	—	—	4
Project principals and staff	—	—	7
Total	59	150	44

[a] Interviews conducted by project principals and staff, June-November 1966.
[b] Held at Saratoga Springs, N Y., Oct. 23-25, 1966

CHAPTER TWO

TRANSPORTATION SYSTEMS AND RELATED RESEARCH NEEDS

Before developing a structure of highway research needs, it was necessary to consider all the modes of transportation which comprise the total national transportation system, the part each plays in moving people and commodities, and their interdependence. No individual mode is completely independent of the others. The highway system, which upon superficial consideration might be considered as independent, is highly dependent on other systems. For example, the motor fuels which power cars, trucks, and buses are, to a major extent, transmitted to consumers from the oil wells and refineries by ocean tankers, pipelines, inland waterways, railroads, and the highway system itself. Many other examples can be cited, such as the use of electric energy to operate highway traffic control devices. Such power is almost independent of the highway system in its generation and distribution, yet it is indispensible to highway transportation.

This interdependence of each mode of transportation, as well as the economy and convenience frequently found in traveling or shipping a commodity through the utilization of two or more complementing systems, clearly demonstrates the need to consider the requirements of any single mode in the light of the total transportation system. This need is especially important in determining the timing and distribution of expenditures for improvements and for research. A knowledge of the maximum benefits to the total transportation system which can result from these expenditures can only be obtained through a clear understanding of the relative importance of the mode under consideration to both the transportation of people and goods and to the efficient operation of the other modes of transportation.

"Mobility is a correlate of progress. . . . The mobility of people and goods is prerequisite for greater economic productivity in the Nation's dynamic economy. . . .

"America's burgeoning city regions will create ever-increasing demands for transport facilities. . . . Mobility is the binding force that unites the modern urban region.

"Future transportation systems must be regional and multipurpose in scope; relate to interregional and national networks; include individual and mass modes in appropriate combinations; and reflect the structure, economy, function, and individuality of the urban regions they serve."(*4*)

A TOTAL TRANSPORTATION SYSTEM

In the United States, as in other advanced nations of the world, the different modes of transportation can be classified under the general category of movement by land, water, and air. On land they can be classified by highway, road, and street systems; by railroad and mass transportation systems; by pipeline systems; and by conveyor systems. On water they include transportation via the Great Lakes and other inland waterway systems as well as maritime shipping. Transportation by air involves the movement of people and commodities over the various regional and national airline systems by commercial, chartered, and private planes.

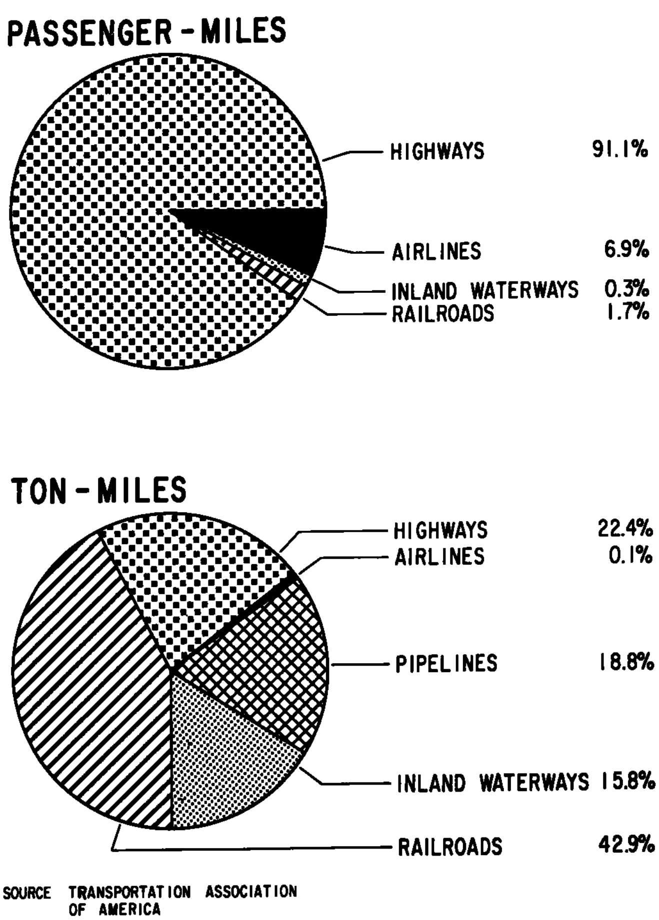

Figure 2. Intercity transportation in the United States in 1966, by mode.

Figure 2 shows the percentages of total intercity travel in 1966 in the United States carried by the principal modes of transportation. It is evident from this that passenger travel by highway accounts for the major proportion of the total amount (91.1 percent), as compared to 1.7 percent by railroads, 6.9 percent by airlines and 0.3 percent by inland waterways. Figure 2 also shows the percentages of the total ton-miles of freight shipped over the national transportation system in 1966 by the various modes and indicates a more even distribution. Railroads carry 42.9 percent, highway systems 22.4 percent, pipelines 18.8 percent, and 15.8 percent is shipped by inland waterways.

These charts show only two important functions of the total transportation system, but they present a general picture of the distribution of intercity traffic among the different modes. However, other factors regarding the importance of the different systems to the total transportation complex must also be understood. For example, although the amount of air travel is considerably less than that by highways, it affords high-speed travel over substantial distances. It is used, therefore, to a great extent by business and professional people and for perishable products. The ability to travel quickly and conveniently has an enormous effect on continued advancement of the national economy and the countless benefits these advances provide to society. Many comparable examples can be cited to illustrate the need to consider the relative positions of each mode in the total system when planning major research activities. At the same time, maximum benefits can only be obtained through the sound use of an interaction between all appropriate modes.

In the urban and metropolitan areas almost all travel to and from other cities must change mode and utilize the streets and arterial systems to reach destinations. Person-trip mileage in U. S. cities is approximately 500 billion miles per year, of which more than 90 percent is in private vehicles (Fig. 3).

The average city resident makes between 2 and 2½ trips per day, where a trip is defined as the one-way travel between points. These trips vary in length, but the vast majority of them average 3 to 6 miles in length and are made in private automobiles occupied by less than two persons. Of the 8½ billion public transit passenger trips per year, more than 6 billion are made in buses and the average trip is 3 to 4 miles in length. More than 2 billion take place in the largest cities possessing rapid transit and street car systems. In those cities transit passenger trips average 4 to 7 miles in length. Commuter railroads provide fewer than 250 million person-trips and these average 15 to 20 miles in length (Fig. 3).

Between 75 and 80 percent of all person-trips begin or end at home. Of these home-based trips, 34 percent are made to or from work, 11 percent for business, 17 percent for shopping, 21 percent for social and recreation, 7 percent for school, and 10 percent for other purposes.

In urban travel, the private automobile plays the dominant role. There are, however, significant exceptions in the larger urban concentrations that must be considered in both research programs and planning policies. To illustrate, in major urban centers, such as Chicago and New York, two out of three persons with destinations in the central city travel by public transport; in peak hours this ratio may be as much as nine out of ten.

Urban streets and highways provide the linkage for the movement of both persons and goods between the terminals of other modes and the scattered locations of factories and homes. Technological innovations, containerization, and modern industrial parks make the highway a facility of ever greater importance. The interplay between transport media within and between cities make multi-modal research especially significant. The interface problems between transportation systems, or travel modes, engendered by parking, packaging, and terminal requirements must be considered.

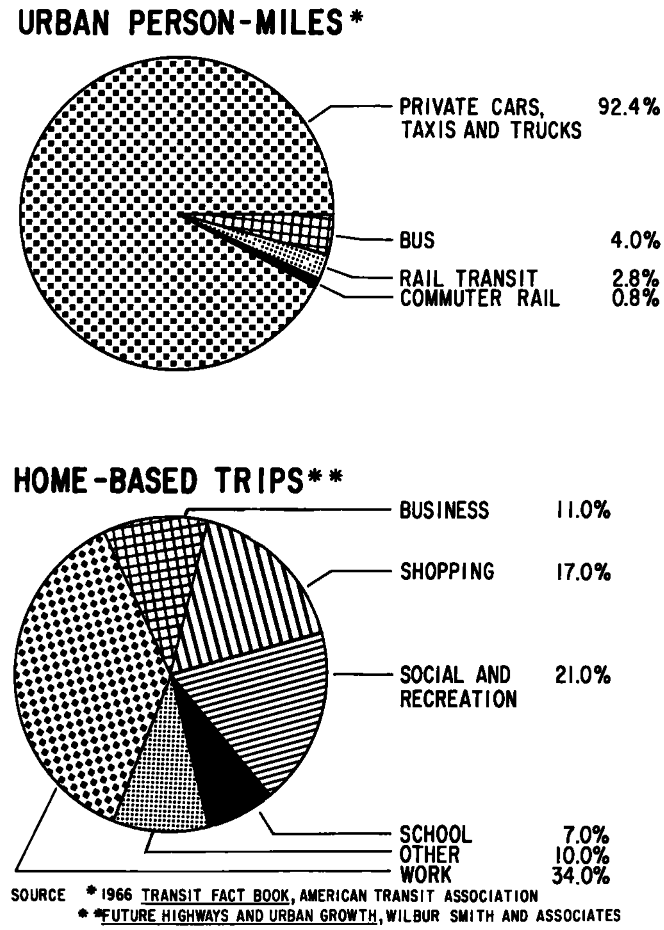

Figure 3. Urban transport, by mode and purpose.

TRANSPORTATION IMPACTS

From time immemorial, the local, regional, and national areas having the best transportation systems also have had the highest socio-economic position. They have been the strongest militarily, the most culturally advanced, and have been afforded the best opportunities for improved standards of living. It is axiomatic that these observations are also valid today. Less certain, however, is the means by which a proper balance between various modes of transportation can be achieved and maintained. This is especially true in a dynamic environment wherein older modes become less important or less efficient while new ones, evolved through technological advance or innovation, assume greater proportions of total transportation needs. Thus, the river and coastal steamers surrendered to the railroads, which in turn have seen the intercity passengers attracted to the airlines. Meanwhile, in the cities, the surface streetcar lines have been removed, and replaced by elevated, surface, or subway rails on private rights-of-way. Street surface vehicles are now rubber-tired buses, trucks, or cars.

It is evident that, through appropriate improvement of transportation facilities, industries and other sources of employment can be attracted to an area. Employment opportunities bring people, increase land values, and, combined with proper planning and zoning, create a new source of wealth for the area and the nation. A growing population is the main force which causes changes in all other demographic and economic factors. This phenomenon occurs repeatedly, for example, when because of increased accessibility new industries develop and residential communities expand in the general corridors of the Interstate System. Depressed neighborhoods in larger metropolitan areas are beginning to be revitalized through urban redevelopment in combination with improved mass transportation, highways, and parking facilities.

The impact of transportation on the military capability and defense of the nation is also of great importance. In this atomic age, it is entirely possible that a nuclear attack on this nation could take place sometime in the future. The best chance for survival in such an event would depend to a significant degree on an adequate, highly efficient, total transportation system.

Future Systems

Potential future transportation systems and facilities certainly include all of those in existence today, but with many improvements resulting from research. Additional and supporting systems of the future may be classified as (1) those which may be rather fully developed in the near future; (2) those of an intermediate future period (evolutionary); and (3) those of the distant future (revolutionary). It may reasonably be expected that high-speed rail transportation, probably with speeds in the vicinity of 150 mph, will soon supplement present-day rail facilities, thereby somewhat relieving regional airlines of their increasing load. Similarly, high-speed hydrofoil transportation facilities may be expected on many of our important waterways, lakes, and coastal areas. In this same period, supersonic air travel, supplementing existing major airline services, can be expected to be integrated into the total transportation system.

Through research and development in the intermediate future a very high-speed ground transportation system may be developed between regions with high travel densities. This possibly may be in vehicles with velocities of 500 to 1,000 mph operating in underground tubes between city terminals. In the distant future, rocket-powered space vehicles may become part of the total transportation system and accommodate very long-distance travel.

National areas of responsibility for improvement, development, and operation of the various transportation systems in the United States are hard to predict beyond the present period. As the more sophisticated transportation systems begin to develop, the costs of research, of the development of prototypes and experimental lines, and of ultimate construction may be so great, compared to initial revenues, as to require substantial Federal aid or some other form of subsidy for each of these phases, including urban transit and highway systems.

CHANGES IN VIEWS AND EMPHASIS

In developing a research program, flexibility is essential for many reasons. Principal among these is that, in the field of transportation, changes in viewpoint, policies, and "styles" are constantly taking place. Such changes are especially apparent at present in the field of urban transportation. For example, the modern concepts of design as related to transportation facilities introduce many new procedures and policies. The multiple use of rights-of-way, the meshing of transport facilities into buildings and other land uses, and the structural coordination of transit modes, are typical of areas in which drastic changes of view are occurring.

The coordination of transport systems leading to development of multi-modal terminals is producing many new policies. Recent requirements regarding detailed studies of ground transportation between urban centers and major airports again reflect changes in emphasis that can have an important effect on transportation policies.

Questions of policies can arise concerning the desirability of present city expansion or the development of new cities.

Severe restrictions on automotive travel in central cities would require many new policies. These have been suggested for many years in some of the major cities.

Accepting public travel as "public service," and discarding the old principle of having it "pay its way," is another example of how changes in policies, particularly in fiscal areas, can affect transport needs and redirect research efforts.

TOTAL TRANSPORTATION RESEARCH OBJECTIVES

It is evident from the previous discussion pertaining to present and future transportation systems that an enormous coordinated research effort is necessary in all transportation modes to achieve appropriate progress in providing facilities to meet rapidly increasing total transportation requirements.

Barring this effort, advances in one field may so outrun those in other fields as to stimulate a major imbalance in the total transportation network. Equally important is a need to exchange major research findings among modes of transportation. For example, many of the electronic guidance discoveries now used in the space program may very well be used in automatic motor vehicle guidance systems and in other traffic control or sensing equipment of the future. Research by the National Aeronautics and Space Administration (NASA) has stimulated and directed channels of research by the tire and highway industries into the improved braking of vehicles and skid resistance of pavements. Similar use of research findings in one field by another can be cited.

It is exceedingly important, therefore, that research results in the different transportation modes be thoroughly disseminated to the other modes so that full advantage can be taken of new knowledge and duplication of efforts avoided. This broader informational clearinghouse responsibility might well be a fruitful function of the newly created U. S. Department of Transportation. As an appropriate and efficient means of achieving this objective, the new department might support an expansion of the established Highway Research Information Service (HRIS) to include coverage of research related to all transportation modes.

One of the major objectives to be sought through research in the various segments of the total transportation system is an optimum balance of the capabilities of the different modes of transportation. Coupled with efficient interchange between these modes, this balance could create and maintain a national system of maximum efficiency, safety, and convenience. Another major objective of transportation research is the establishment of appropriate criteria and planning procedures for the development and expansion of balanced local transportation systems necessary to maintain or reestablish greater community values in the major metropolitan areas of the United States and to stimulate the development of other communities throughout the nation in accordance with the national interest.

The efficiency of a transportation system is enormously important in the military defense of a nation. It is obvious, therefore, that another national objective of research in the total transportation field lies in an improvement of the flexibility of interchange between the various modes of transportation for military movement of personnel and materiel. Research into methods of constructing or providing for emergency increases in the capacity of transportation system facilities is also implied.

Inasmuch as the total transportation system is important to every aspect of modern living, a national objective in transportation research logically appears in the area of national health and welfare. It is desirable that effective use be made of all knowledge obtained through past, present, and future research and development to optimize the safety, convenience, efficiency, and cost of transportation.

Much of the rapidly increasing pollution of air, especially in major metropolitan areas, is caused by transportation facilities through the burning of gasoline, kerosene, and various diesel fuels. Even electrically operated transportation facilities may participate in air pollution wherever generation of electricity is accomplished by steam plants. If pollution continues to develop as it has in recent years, it may become so critical that it will require precipitous action, which is always costly and inconvenient. Another national objective of transportation research, therefore, is related to the development of efficient means for limiting air pollution. In the same general area of public welfare, noise abatement, without reasonable loss of power, is an important research objective for both surface and airborne vehicles.

To place highways and highway research needs in proper perspective, various types of transportation systems, interrelationships, and research objectives were discussed in this chapter. Formal transportation research goals are proposed in Chapter Five. The next chapter takes a look at the past and reviews the history of highway research.

CHAPTER THREE

DEVELOPMENT OF HIGHWAY RESEARCH

The history of highway research and development parallels the growth of highway construction in the United States. The following discussion enumerates the various organizations with responsibilities or interests in highway transportation research. Historic trends in research activities are also presented.

In addition to the valuable work of the States, much highway research has been sponsored or undertaken by the U. S. Bureau of Public Roads and by the Highway Research Board. A few cities and some county road agencies make valuable research contributions to the highway transportation field. University and private research agencies add important efforts, and many improvements of products, new products, and processes come from the research efforts of industry.

Recently, substantial research efforts related to highway transportation have been made by other Federal agencies, including research task groups of the U. S. Department of Commerce, Department of Health, Education and Welfare, Department of Housing and Urban Development, and the Department of Defense. Research also is receiving emphasis in the new Department of Transportation.

HIGHWAY RESEARCH BOARD

The need to coordinate highway research crystallized in 1920 when the Highway Research Board was formed under the aegis of the National Academy of Sciences with the cooperation of the American Association of State Highway Officials. The Highway Research Board first provided a forum where all interested in highway construction, maintenance, administration and operations could gather for an annual interchange of newly developed knowledge. Between annual meetings, the Board provided the coordination and editing necessary for the publication of proceedings and technical reports; it maintained contact with the highway departments, universities, and others concerned with highway transportation.

With the organization of highway planning survey sections in the State highway organizations, the research discussions broadened to include traffic, operations, economics, and planning subjects. As annual meeting attendance increased, the Board provided the means for better liaison between researchers. With additional financial support from the States and the Bureau of Public Roads, the Board was able to expand its service through the establishment of the Highway Research Correlation Service in 1945. Also, the Board undertook to supervise and administer certain cooperative research projects, of which the principal ones were Road Test One-Md., the WASHO Road Test, and the AASHO Road Test.*

A special report (*5*) published in 1959 defined the needs, the expenditures, and the applications which the Special Committee on Highway Research Priorities was able to solicit from the member departments. The special committee defined 19 broad areas of highway research (Table 2) which it judged to be of top importance and urgency.

These areas, which comprised a program estimated to cost $34 million, are still a valid list of current research needs. Much of the work in the years since 1959 has been aimed at the solution of a number of those problems. However, although work was done on the proposed program during the past several years, it has been a somewhat fragmented attack with several changes in emphasis. Organization and funding have been slower than anticipated, so that a reappraisal of the effort is now in order.

National Cooperative Highway Research Program

In 1962 the Board developed and undertook administration of a National Cooperative Highway Research Program supported by AASHO in cooperation with the BPR. The program administered through this cooperative effort has been divided into the 20 specific areas of research given in Table 3.

STATE HIGHWAY DEPARTMENTS

Highway research in the States has been spasmodic. All have testing facilities (laboratories), but of the 50 States

* The AASHO Road Test (1955-1961) was conceived and sponsored by the American Association of State Highway Officials as a study of the performance of highway pavement structures of known thickness under moving loads of known magnitude and frequency.

TABLE 2

SPECIAL AREAS OF NEEDED RESEARCH AS OUTLINED BY THE HRB SPECIAL COMMITTEE ON HIGHWAY RESEARCH PRIORITIES (1959)[a]

1. Controlling development of land in vicinity of freeway interchanges.
2. Design, traffic control, and spacing of ramps and interchanges.
3. Intensive investigation of accidents.
4. Comprehensive study of passenger transportation in metropolitan areas.
5. Comprehensive study of freight transportation by motor vehicle in rural and urban areas.
6. Translation of the results of the AASHO Road Test in Illinois to conditions in other States.
7. Snow and ice removal or treatment.
8. Improvement of highway maintenance.
9. Improvement of knowledge of aggregates and soils.
10. Improvement of techniques for forecasting traffic and revenues.
11. Sharpening of figures of tangible road-user benefits and development of method for appraising benefits now called intangible.
12. Conceptual study of non-user and community benefits of highway construction in relation to user benefits.
13. Warrants for lighting freeways.
14. Standards for secondary and local roads.
15. Development of driving simulator.
16. Electronic control of vehicles.
17. Analysis of the interactions of road and vehicle.
18. Simulation of traffic flow.
19. Improvement of motor vehicle administration.

[a] Ref. (5).

TABLE 3

RESEARCH PROJECT AREAS OF THE NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

ADVISORY PANEL	SECTION	SPECIFIC AREA OF RESEARCH
Administration	2	Economics
	11	Law
	19	Finance
Transportation planning	7	Traffic planning
	8	Urban transportation
Design	1	Pavements
	12	Bridges
	15	General design
	16	Roadside development
Materials and construction	4	General materials
	9	Bituminous materials
	10	Specifications, procedures and practices
	18	Concrete materials
Maintenance	6	Snow and ice control
	13	Equipment
	14	Maintenance of way and structures
Traffic	3	Operations and control
	5	Illumination and visibility
	17	Safety
Special projects	20	Highway Research Information Service
	20	Research needs in highway transportation
	20	Traffic capacity and safety
	20	Future transportation preference

and the District of Columbia and Puerto Rico, 19 have no formal research organization. Generally, the State research programs have consisted of individual projects designed to find answers to specific problems. In many instances, projects are conducted in cooperation with State universities, engineering schools, consultants, or research foundations. Often the in-house State highway research is conducted by the materials and testing division at the department laboratories. Traffic and other transportation matters may be researched by other bureaus. Only occasionally do the individual States embark on research problems of more than local interest, although they regularly exchange ideas and research results with other States and provide leadership for research oriented toward the solution of State, city, county, and local road problems.

In addition to the NCHRP, several coordinated projects among groups of States have been accomplished. A typical one is the Freeway Surveillance, Control and Traffic Aids Project, a 13-State sponsored research project on freeway surveillance and electronic aids utilizing the John Lodge Freeway in Detroit.

American Association of State Highway Officials

The various State highway commissioners organized the American Association of State Highway Officials in 1914. It is composed of the operating heads of the highway departments of all 50 States, the District of Columbia, Puerto Rico, and the Bureau of Public Roads. Operating through various committees, highway research of national interest is discussed and planned by AASHO. For the execution of the research, however, and for the dissemination of research results, the AASHO committees generally rely on the Highway Research Board.

BUREAU OF PUBLIC ROADS

At the turn of the century the forerunner of the BPR, the Office of Road Inquiry, was building "object-lesson" roads throughout the country to demonstrate the best road-building methods. It was not until the 1930's, when the State highway planning survey sections were created, that the BPR was engaged extensively in research. In 1962, "planning" and "research" functions were separated; now the BPR has an independent Office of Research and Development with about 276 staff members, 159 of whom are professionals. The budget for research has increased rapidly, even though it is still inadequate when measured by today's needs.

The BPR in 1965 prepared a "National Program of Research and Development for Highway Transportation" (*6*) with three high-priority problems and seven program goals subdivided into 28 major projects (Table 4). The total

TABLE 4

NATIONAL HIGHWAY RESEARCH AND DEVELOPMENT PROGRAM AS PROPOSED BY THE BUREAU OF PUBLIC ROADS [a]

PROGRAM GOALS	MAJOR PROJECTS
PART A: NEW CONCEPTS RESEARCH (Theoretical)	
1. Definition of underlying requirements for highway transportation	1. Factors underlying choice of transportation 2. Economic models of urban transport efficiency 3. Analysis of the functions of highway transportation
2. Analytic definition of complex traffic movements	1. Stream flow 2. Network flow
3. Development of improved analytic techniques for designing the components of highway transportation systems	1. Material characteristics and behavior 2. Dynamic stresses in structural systems 3. Driving control processes 4. Stream-bed stability adjacent to structures 5. Behavior of pavement system components under cyclic stress
PART B: NEW METHODS RESEARCH AND DEVELOPMENT (Applied)	
4. Development of methods for reliable forecasting of demand for highway transportation	1. Economic consequences of highway transport to the road user 2. Effects of highway treatment on local economies 3. Underlying factors in urban transportation analyses
5. Development of methods for increasing capacity, control and safety in traffic movement	1. Accident prevention and minimization 2. Improved utilization of high-speed highways 3. Improved performance under adverse environmental conditions 4. Optimization of flow on city streets
6. Development of techniques for more precise structural design and incorporation of new materials and structural concepts	1. Optimum design concepts for bridges and pavements 2. Reliable prediction of performances of present designs of structural systems 3. Criteria for bridges and pavements of the future 4. Improved performance, economy, and durability of materials and materials systems 5. Improvement and utilization of natural materials for highway construction 6. Protection against natural hazards 7. Utilization of fundamental properties of materials for specifications as related to performance
7. Development and application of new technology to the location, design, construction and maintenance processes	1. Total integrated engineering systems 2. Construction processes and control 3. Maintenance operations and management
8. Other staff, contract, or HRP projects or tasks not a part of the National Program but of major, local, regional, or national importance	

[a] Ref. (*6*).

program includes areas in both theoretical research and applied research. Many proposed research projects, tasks, and subtasks are molded into the program. Revisions were made in July 1966, and the program is undergoing continued refinement as suggestions are made by the State highway departments and other agencies. It is estimated that the program, as presently proposed, will cost about $100 million and will require from five to eight years to complete. The three high-priority problems in the BPR program are concerned with:

1. Requirements of urban transportation.
2. Reduction in costs of construction and maintenance.
3. Measurements of the socio-economic impacts which accompany current highway programs.

OTHER U. S. GOVERNMENT AGENCIES

Other U. S. government agencies have stated current research objectives in the highway transportation research field.

The *Department of Housing and Urban Development* is concerned with the ways and means of redeveloping substandard portions of American cities. Modern housing and improved transportation are the essential ingredients of redevelopment. Special emphasis is on the improvement of transportation in the central areas of cities through the Urban Transportation Administration so that the daily tidal flow of people, especially workers, can be accommodated. In this connection, research has been undertaken primarily in the form of mass transportation demonstration projects aimed at relieving the stresses and discomforts of daily commuting in cities.

The *Office of High-Speed Ground Transportation* in the Department of Transportation has under way research aimed at improvements in intercity passenger and freight movements, especially along the eastern seaboard between Washington and Boston—the "Northeast Corridor."

The *National Highway Safety Bureau,* also in the Department of Transportation, is responsible for research in highway and vehicular safety.

The *Department of Defense* conducts research concerned with highway and airfield construction. It also researches means of transportation of personnel and goods on military and naval establishments, and in potential military action. Considerable research in transport logistics has as its objective the improvement of transportation of materiel from factory to warehouse, to various military and defense establishments, and to the point of military or naval use.

The list of Federal agencies involved in highway transportation-related research could be greatly extended. For example, significant research in human behavior and health by the *Department of Health, Education and Welfare* is most important to highway technology. Studies by the *Department of the Interior* on travel demands and characteristics to and from parks and recreation areas are producing important findings. The *Interstate Commerce Commission* has long been concerned with driver standards and regulation of commercial vehicles. The *Bureau of Standards* has engaged in basic transportation research.

COUNTY, CITY, AND LOCAL ENGINEERING DEPARTMENTS

County, city, and other local agencies are not especially active in highway transportation research. However, much has been done by the State and county highway staffs by improvising and investigating new methods, new ideas, and new devices to improve the techniques and services of various facilities within the transportation complex. Generally speaking, the departments of the city have been primarily concerned with applied research; that is, they have been seeking solutions to day-to-day problems. They have sought to improve products through increasing knowledge of the behavior of materials or techniques in construction and maintenance.

Important gaps in local research are often filled by cooperative efforts with State highway departments or national associations.

The *American Public Works Association (APWA) Research Foundation* published in November 1963 a special report entitled "Public Works for the Future" (*7*), in which 20 research project areas were suggested in the field of transportation (Table 5). The purpose of this program is to make it possible for local units of government jointly to solve public works problems by cooperative financing through the Foundation. Thus, larger sums of money and services of highly competent technicians and professionals can be secured. This nonprofit organization determines needs, presents selected research proposals to local government officials for consideration and evaluation, and after securing cooperative financial support processes projects to completion and presents results to participating governments.

UNIVERSITIES AND RESEARCH CENTERS

The roster of universities and research centers concerned with highway transportation is extensive. Current research undertaken by these institutions covers many fields. Some studies are concerned only with the "state of the art." Others are broad and profound, including such things as changes in vehicular transportation, prospective advances in vehicle guidance, automation of the highway, and improvements in vehicular communication systems. The research staffs and facilities available at university research centers, engineering colleges, and graduate schools, often through the utilization of graduate student help, single researchers, or small research teams, have been responsible for leadership and substantial accomplishments.

Many educational agencies have developed, or are developing, major transportation research facilities. The work undertaken by such well-known institutions as Purdue University, Northwestern University, Iowa State University, Massachusetts Institute of Technology, University of California, Yale University, Texas A & M University, Cornell University, and the University of Illinois are well known. Significant new facilities are being planned at Ohio State University, the University of Michigan, and elsewhere.

ASSOCIATIONS AND PRIVATE INDUSTRY

Professional and technical associations are actively supporting research in problems confronting their membership. The *American Society of Civil Engineers* has under way, at the time of this report, a study jointly sponsored with the National Science Foundation and Colorado State University to analyze research needs in civil engineering. As a part of this study, the Committee on Research of the Highway Division of the American Society of Civil Engineers developed a structure of highway transportation research needs and divided these needs into four broad categories, as follows:

1. To improve planning processes.

2. To improve system operation.
3. To improve physical performance.
4. To improve management procedures.

Since 1964, the *American Institute of Planners* has fostered planning research through its national headquarters staff. It has been increasingly concerned about the emerging new cities and megalopolis complexes of America and the problems of properly integrating transportation and land-use plans. The Institute's list of problems needing research (Table 6) suggested a six-year program aggregating $225 million. It is currently being updated by the recently established A.I.P. research staff.

Similarly, the *Institute of Traffic Engineers*, through its eight technical departments, has sponsored research and technical reports dealing with many matters of interest in traffic engineering. Twenty-seven committees are engaged in investigations of problems assigned by the eight departments of the Institute.

The *Transportation Association of America* surveys current and potential transportation research projects of a policy nature. This association of private transportation operating companies biennially publishes a report of research projects that affect management and economic or social aspects of transportation policy. The research projects include air, rail, pipeline, and waterways. Inasmuch as the Association membership includes transport operators, much of its research interest is in the fields of traffic management, marketing, pricing, accounting regulation, taxation, and labor-management relations (see Table 7).

Many industrial and trade organizations associated with the highway industry have their own laboratories and also participate in research with educational institutions and with the Highway Research Board. Examples are The Asphalt Institute, the Portland Cement Association, the Automotive Safety Foundation, the American Transit Association, and the Automobile Manufacturers' Association. Much of the research of the industrial organizations is devoted to materials and products, many of which later find their way into common use in the highway and transportation industry. Industry's willingness to share in the national research is indicated by more than $2 million of direct participation in the AASHO Road Test.

The foregoing is a brief review of the organizations concerned with highway research. Research on vehicles has been left almost entirely in the hands of private enterprise. There has been little Federal assistance, and that mostly from developments peculiar to the needs of the Department of Defense. This research has resulted in some spin-off for vehicle manufacturers. In the past year there has been action on the part of the Federal government in vehicle research, because of increased emphasis on safety and air pollution.

Relatively little research effort has been devoted to the third element of highway transportation—the human element—the driver. Research in the human behavioral sciences is difficult to quantify and apply to the physical entities of a highway system.

In summary, practically all highway transportation research has been performed on its individual elements. Although there has been reciprocal consideration given by the highway designer and the motor vehicle designers, consciously or unconsciously, to improvements in the other's product, no real concerted effort has been apparent to examine or research highway transportation as a system.

TABLE 5

NEEDED RESEARCH, AS PROPOSED BY AMERICAN PUBLIC WORKS ASSOCIATION RESEARCH FOUNDATION [a]

1. The development of scientific parameters for evaluating present and future means of urban transportation.
2. More efficient utilization of existing streets.
3. How to forecast urban traffic patterns.
4. Improving public compliance with speed laws by using computers and remote-controlled signs to indicate the optimum speed for a given set of traffic conditions.
5. Study of individual habits and reasons for favoring a specific mode of transportation.
6. Study of methods for controlling the development of land in the vicinity of freeways and freeway interchanges.
7. Spacing of ramps and interchanges on freeways.
8. Study of factors which influence driver behavior.
9. Development of methods for improving the interchangeability of freight shipments among various modes of transportation.
10. Development of legal means for enabling and promoting cooperation and coordination among neighboring government agencies in urban areas.
11. Comparative evaluation of pavement types and designs most suited to specific kinds of soils and climatic conditions.
12. Development of methods for improving the load-bearing characteristics of inferior soils.
13. Development of additives for asphalt and concrete pavements to prevent the formation of ice and to prevent slipperiness in wet weather.
14. Development of a pavement or surfacing material resistant to weathering (freezing and thawing) abrasion and to the corrosive action of salts used in ice removal.
15. Electronic vehicle control devices to increase highway speed and safety.
16. Optimization of manpower and equipment use in snow removal operations.
17. Development of devices for complete and rapid removal of snow and ice from streets and highways.
18. Coordination of street planning with urban highway planning for optimum public benefit.
19. Studies to determine the relative benefits of various types of freeway lighting.
20. Improvement of nighttime visibility on highways.

[a] From Ref (7)

TRENDS IN HIGHWAY RESEARCH

Because highway transportation and the research supporting it is a multi-organizational cooperative effort, there have been few clearly identified national research objectives or goals which have found common acceptance by all agencies. These objectives, therefore, must be inferred from the past and current efforts and concerns of engineers and administrators; planners, economists and sociologists; and

TABLE 6

RESEARCH NEEDS RECOMMENDED BY AMERICAN INSTITUTE OF PLANNERS [a]

1. Guidelines for planning urban and regional development programs.
2. Technological analysis for regional development.
3. Techniques for regional planning.
4. Policies for the guidance of regional planning agencies.
5. Basic development analysis for regional planning.

[a] Ref. (*8*).

TABLE 7

MAJOR TRANSPORT POLICY RESEARCH NEEDS AS PROPOSED BY THE TRANSPORTATION ASSOCIATION OF AMERICA [a]

1. Effect of regulation on the ability of the different modes of transportation to meet normal and defense requirements:
   (a) Deregulation of transportation
   (b) Long-range planning by regulatory agencies
   (c) Cost characteristics in rate-making
   (d) Changing competitive relationships
   (e) Earnings and capital investment financing
   (f) Illegal transportation practices
   (g) Emergency transport capacity
2. Relationship of government, other than through regulation, to the transportation industry:
   (a) Subsidy and user charges
   (b) Taxation inequities
   (c) Municipal ownership:
      (i) Urban transport
      (ii) Railroad commutation
   (d) Transportation developments abroad
   (e) Government competition
   (f) American merchant marine
3. Roles and relationships of common, contract, exempt and private carriers:
   (a) Growth of private carriage
   (b) Volume rate innovations
   (c) Systems analysis techniques
   (d) Small shipments
4. Causes and effects of technological lags in the transportation field:
   (a) Management and financing
   (b) Labor practices and employment dislocations
   (c) Intermodal coordination

[a] Ref. (*9*).

others engaged in providing and operating transportation systems.

Research in general has responded to two elements generating problems and research needs. The first is the highway building program. Distinct building programs have included: farm to market roads; various Federal-aid programs, starting with post roads; and, finally, the Interstate highway program. Problems initially were those dealing with gaps in knowledge of physical conditions—first for the designer, then later for the operator and the maintenance engineer.

Administrative, public, and political interests and opinions are the second element that have generated research needs. They fall more in the domain of the social and behavioral sciences than the physical sciences. As both the human and vehicle populations have burgeoned, so has the need for solutions to these "soft" problems. Such problem areas as safety, urban congestion, land-use, and aesthetic values, although always in the background, are increasing in importance. Public demands for solutions are likewise increasing.

Much of the early highway research was concerned with materials, equipment, and techniques for construction; the principal inquiries in the highway research field were concerned with how to build stable wearing surfaces suitable for the vehicles of that time and of the future. Later, with the increasing use of vehicles, and the extension of road surfaces, accidents became a major problem. With increased accident frequency and severity, emphasis on safety became paramount in design. Major research was concerned with interactions of vehicle performance and roads and streets. Designs were altered to match new vehicle capabilities. As traffic volumes increased, research developed improved signs, signals, markings, and other traffic control devices. In recent years, signal systems have been improved to permit better progressive traffic flow over street networks, thereby producing increased efficiency and greater safety.

In 1959, *HRB Special Report 55* (*5*) summarized highway research problems of importance derived from the various departments and committees of the Highway Research Board, as well as the individual highway departments, other interested agencies, and individuals. In comparing the areas of research projects provided by the High-

TABLE 8

DISTRIBUTION OF HIGHWAY TRANSPORTATION RESEARCH PROJECTS, BY RESEARCH AREA

RESEARCH AREA	DISTRIBUTION (%) SUGGESTED 1959 [a]	UNDERWAY 1965 [b]	INTERVIEWS 1966 [c]
Economics, finance, and administration	26	8	21
Design	18	22	15
Materials and construction	22	28	14
Maintenance	3	3	9
Traffic and operations	17	19	23
Soils, geology, and foundations	11	14	3
Legal studies	—	2	2
Urban transportation planning	3	4	13
All	100	100	100

[a] Ref. (*5*, p. 23).
[b] HRIS compilation (Sept. 1965).
[c] Needs suggested during interviews conducted for this study.

way Research Information Service (Table 8), a good correlation is found between the needs in 1959 and actual studies under way in 1965, particularly in design; materials and construction; maintenance; traffic and operations; and soils, geology, and foundations. It appears that in each of these areas the effort is about 20 percent greater than suggested in 1959 in terms of the number of projects.

In these categories, the suggested needs for 1967 show (a) less emphasis on design problems; (b) only one-half as much interest in problems connected with materials and construction; (c) a substantial increase in the attention given to economics, urban transportation, and maintenance; and (d) a substantial decrease in the relative amount of effort suggested for soil, geology, and foundation studies.

It is interesting to note that the percentage distribution of needed research problem areas suggested in the interview survey of 1966 closely approximates those suggested in 1959, except for the major shift from soil studies to urban transportation planning.

This chapter has discussed the various organizations involved in highway research and some of their research activities. Also indicated were the research needs which they have identified for their own programming purposes. In the following chapter research needs are presented which were developed in the interviews and at the symposium conducted as a part of this study.

CHAPTER FOUR

HIGHWAY RESEARCH NEEDS AND ADMINISTRATION

In this chapter, the material obtained from the search of existing literature on highway research needs is discussed, together with the views expressed by the persons interviewed and the participants in the symposium. Findings relative to the present organization of research efforts, and criteria and methods used in delineating research programs of various agencies, are summarized.

LITERATURE SEARCH

In an attempt to discern those significant problem areas within which highway transportation research is currently concentrated, the available literature regarding on-going highway research programs was reviewed. On the national level, the activities of the U. S. Bureau of Public Roads, the Highway Research Board, the American Society of Civil Engineers, the American Public Works Association, the American Institute of Planners, the Institute of Traffic Engineers, and the Transportation Association of America are typical of the significant programs about which published information is available.

Several areas of common interest are noted in these programs. Although the subdivisions vary in number and detail, generally they can be grouped into four common areas designed to improve the planning process, system operations, physical performance, and management. Under the *planning process*, common research areas include the need for more knowledge on the basic understanding of traffic flow, techniques for making traffic forecasts, and improving the integration of the highway structure with emphasis on the socio-economic impacts. Under *system operations*, research needs in optimizing service, safety, and maintenance of existing highway facilities are repeated. To improve *physical performance*, knowledge gaps in techniques of design and construction, and in the use of improved materials, are repetitive. Under *management*, research needs are expressed by all agencies, but they are given particular emphasis by the Transportation Association of America and the American Institute of Planners.

INTERVIEWS

The interview program was established to obtain current opinions from government and industrial leaders on a variety of subjects germane to research needs in highway transportation. The topics covered during the interviews included:

1. Opinions of what a structure of highway research needs should look like; i.e., should it reflect priority, ultimate benefits, general and broad ideas of interest.
2. Knowledge of existing research structures or programs which might be recommended as a guide or for information.
3. Suggestions on objectives and scope of highway research activities.
4. Information about existing methods for establishing research programs and opinions on how such methods can be improved, or ideas on completely new approaches to developing research programs.
5. Methods for relating or evaluating economic and social benefits of research accomplishments.
6. Ways of assigning costs and priorities to research.
7. Ideas on estimating the time needed to accomplish specific research.
8. Ideas and suggestions on ways to improve dissemination and implementation of research findings.
9. Problem areas of concern to the interviewee, and the interviewee's estimates of costs for problem area study.

The interviews were not productive in all these areas. Little information was forthcoming on structuring, funding, or priorities. The problems of personnel and budgets tended to limit true research efforts to projects of immediate, short-range nature. Many interviewees indicated the need for exchange of ideas between research and operating personnel. Their diverse educational and practical experience often hindered application of research findings. Despite many exploratory questions on the list of interview topics, the discussion largely revolved about problem areas needing further research effort in the opinion of the interviewees.

In the interviews conducted with highway officials and other persons involved in the highway program or in research areas related to the highway program, a significant trend in the problem areas or areas of concern to this group was apparent. In spite of the major research emphasis on the part of the State highway departments in the areas of materials, construction procedures, design criteria, and quality control, there is a decided broadening of the concern about those unknown factors outside of the highway plant which are bearing more and more heavily upon the highway program.

Foremost among these factors is the integration of streets and highways with the total transportation system. This area of concern was mentioned by more intreviewees than any single other item identified as a problem area. Obviously, this repeated mentioning reflects the distress of urban transportation systems, which along with the urban redevelopment problems have been subjects of Congressional committee hearings and national publicity during 1966 and 1967. The U. S. Department of Housing and Urban Development was created in 1962 and the Department of Transportation late in 1966 in response to such problems. Persons interviewed were concerned over a variety of subdivisions of this problem covering the design of transportation interfaces, the prediction of modal splits, the multiple use of rights-of-way, the improvement of transportation demand analyses, and a variety of other factors related to an integrated transportation system.

Second only to the integrated transportation system as a major area of concern to the interviewees was the growing problem of urban land use. A variety of subdivisions of this problem area included the economic impact of highways upon the community, the social impact of highways upon the community, the improvement of land-use planning techniques, and the system approach to urban land-use planning, in which the highway and other urban facilities would comprise an integrated system with compatible and complementary features.

The field of traffic control, traffic flow and traffic estimating also was one of continuing concern to interviewees. Another major problem area discussed by many interviewees was the general problem of accident reduction on the highway system and safety considerations in design, construction, and operations.

Ranking next in frequency were the problem areas related to materials; the improvement and optimum use of existing highway facilities; and the problem of accommodation of parking, or vehicle storage, in urban areas. The needs to incorporate improved maintenance in the original design, and to develop new maintenance techniques for modern high-speed highways were brought out.

A variety of other problems discussed were related to pavement surface conditions (such as the need for more adequate reflectorization and skid resistance), the future structuring of cities and urban areas, the effective identification and consideration of highway aesthetics, the need for improved quality control in highway construction, and transportation economics.

In interviews with industry officials, especially those representing the suppliers of road-building materials and equipment, the suggestion often was made that the HRB, AASHO, or a similar agency could serve a valuable function by helping States, individually or by regional groups, provide proving grounds for new industry developments.

In addition to the research problem areas of primary concern to the interviewees, it was significant to note the variety of comments related to current national highway research activities. Some of the interviewees expressed continuing anxiety about the tendency to centralize research efforts under Federal direction. There was concern about overcontrol of researchers and research efforts on the part of research sponsors. On the other hand, there was concern over the academic approach, which to some resulted in too little immediate "payoff" and only led to continuing research. There was agreement that qualified research personnel are scarce and the existing requirement for competitive proposal submission results in a loss of research effort by all but the successful research agency. Others expressed the view that the practice has developed proposal writing experts whose research abilities may not be reflected by the proposal, or whose capabilities may not be available for the research project. There was a strong feeling that the research effort, nationally and locally, has been too small both in total program and in individual research projects. The general feeling appears to be that research efforts should be packaged in major *problem-oriented categories rather than in short-term projects.*

Significant concern was expressed over the long time lag between the drafting of a project statement in response to a research need and the actual initiation of the research study. The internally-generated problem of not only selecting, storing, and retrieving research information, but also of implementing and using knowledge generated by research was frequently mentioned. Generally, it was felt that the research program responsibility should not end with the publication of voluminous research findings but should continue through a stage of evaluation and dissemination of pertinent research data in a concise and direct form which could be utilized by engineers engaged in the on-going highway program.

SARATOGA SYMPOSIUM

At the Symposium on Highway Transportation Research Needs, held at Saratoga Springs, N. Y., 44 experts * representing Federal, State, university, private, and other or-

* See Appendix A for list of participants

ganizations and agencies involved in transportation and related research suggested a broader range of problem areas for consideration. Reflecting, perhaps, the wide diversity of disciplines present at the conference, the problem areas discussed were given equal importance without any single major area receiving a preponderance of expressed concern. The three symposium panels are outlined in Figure 4.

One dominant theme in the discussion of research problem areas was that related to the optimum use of the existing street and highway system. Here the conferees suggested continuing research in the field of traffic control, traffic network analysis, the employment of driving-aid mechanisms, the improvement of maintenance procedures and maintenance technology, the determination of need and provision of better emergency service to the highway user, the qualification of environmental effects (pollution. noise, and the like) of the highway upon the adjoining land areas, and the determination of optimum loadings (sizes and weights) of highway vehicles.

The second main theme of the symposium members' discussion on problem areas related to urban development and land use as affected by or related to highway transportation. Of concern here were the economic and social impacts of highways upon the community, the interaction of highway development and community development, the design concepts under which highway development takes place in the community, and the interaction and integration of the highway transportation system with the other transportation systems serving and shaping the urban areas.

Other areas of concern discussed by the symposium members included integration of the vehicle with the highway through further analysis and understanding of vehicle characteristics and through the continuing improvement of vehicle design and performance. Transportation finance and the problems related to the economic interplay of the highway system and the area it serves were discussed.

In addition to the research problem areas discussed by the symposium members, several other topics of general interest were included in the discussions.

First, concern was expressed about the need to implement research findings. The need to apply present knowledge to problems continues to represent a difficult task with the complexity of research programs and administrative jurisdictions involved in this effort. It was further noted that the implementation problem goes beyond the bounds of the highway industry, inasmuch as it is equally important to tap the research resources in fields entirely different from highways. For example, research in the fields of propulsion, vehicle guidance, communications, and human engineering for the space program may have invaluable applications to the highway transportation system as well.

Another element suggested as contributing to the effective implementation of research findings would be establishment and maintenance of a national statistical library of highway data. Such a data source would provide reliable and valuable data for a variety of research projects, each of which may now be dependent on its own data collection capabilities.

The difficulty of properly balancing the research effort to reflect the need for greater knowledge in the socio-economic fields, while still meeting the pragmatic demands of the highway administrator faced with more fundamental problems in materials and structural design, was evident during the symposium discussion. It was noted that the research funds of the BPR are almost evenly divided between physical research and the so-called "soft research" areas. The HRB-administered program (NCHRP) has been divided so that approximately 40 percent of the funding effort is directed toward the physical or "hard research," and 60 percent toward "soft research." It was also pointed out that the changes in the highway transportation system have been and will continue to be evolutionary rather than revolutionary, and the research efforts should anticipate this type of development.

The foregoing programs and the objectives or areas of emphasis in these programs reflect a growing national awareness of the necessity, first, to conduct intensive research in the field of highway transportation if the transportation system is to cope effectively with the demands it faces, and, second, that this research must be directed and coordinated if maximum benefit is to be derived from the research effort.

PANEL A

"OBJECTIVES AND APPROACHES TO HIGHWAY TRANSPORTATION RESEARCH"

Moderator: L. G. BYRD
Panelists . J. BURCH McMORRAN
ROBERT F BAKER
J. DOUGLAS CARROLL
C. M. THOMAS

PANEL B

"DELINEATING AREAS OF PRESENT AND FUTURE HIGHWAY TRANSPORTATION RESEARCH NEEDS"

Moderator: PAUL E. CONRAD
Panelists: JOHANNES F SCHWAR
EDWIN N. THOMAS
ROBERT C. HEDLUND
JAMES DeLONG

PANEL C

"ASSIGNING PRIORITIES, COSTS AND RESPONSIBILITIES FOR HIGHWAY TRANSPORTATION RESEARCH"

Moderator: WILBUR S. SMITH
Panelists : WILLIAM N CAREY, JR.
HAROLD F. HAMMOND
THEODORE F MORF
WILLIAM PENDLETON

Figure 4. Panel structure of Symposium on Highway Transportation Needs, held at Saratoga Springs, N.Y., October 23-25, 1966.

ORGANIZATION AND ADMINISTRATION OF THE RESEARCH EFFORT

Although indirectly related to the objectives of this study, substantial discussion during the interviews and at the symposium was devoted to the inherent problems of organizing and administering the research effort. While individual research projects are usually well directed, and agency-sponsored programs are reasonably specific, a growing need exists for definitive objectives to give direction to highway research on a national level. Such well-defined objectives can serve several important purposes. The clear definition of major research objectives can produce coordination of national effort toward the accomplishment of such objectives to a degree that does not now exist. These objectives will also permit the elimination of duplicate effort, the interchange of findings at the lower level of research, and the concentration of effort on achievable objectives.

A valid and meaningful measure of research accomplishments is permitted when the results of the research effort are related to a clear objective. The evident absence of clearly expressed, coordinated goals and objectives at the national level is, no doubt, a contributing factor in the fragmentation of research efforts and in the limited funding of today's research effort. The selection of proper research objectives and the communication of these objectives to the highway fraternity and to the highway user can provide a dramatic focus on the national research effort. Important specific achievements can be directly attributed to the research program, thereby improving support for such a program at the administrative and public levels.

In private industry, on the other hand, research programming must be closely related to the marketplace. The probability of research payoff and the impact of the research payoff in terms of market and sales must ultimately guide the priorities of the research program. Here, a basic enigma often faces private industry executives responsible for research programs. If the industry's research effort is sufficiently successful to permit development of a superior product over which there is proprietary control, the industry may find itself without a market for the product inasmuch as public agencies responsible for the highway program are reluctant, if not legally restrained, from specifying proprietary items as a part of highway construction and maintenance.

Programming Alternatives

During the interviews, research objectives were sometimes confused with highway program objectives. Generally, highway programs are based on known factors while highway research objectives are predicated on unknown factors. For example, the completion of construction of the Interstate Highway System is the objective of a dramatic highway program, which could use known highway technology, whereas the integration of the highway with the community is the objective of a broadly-based research effort predicated on the development of new (unknown) technology and concepts. These factors are important considerations in the development of active research programs for which several approaches were revealed during the study.

An example of research organized around stated objectives is the BPR research program, where project selection is based on a three-part analysis. The first step considers the significance of the proposed work as a major national or local problem, the potential benefits to highway transport, the probability of meeting the objective, the potential solution to a specific problem, and whether or not the study is a duplication of work already done or under way.

Secondly, the total adequacy of the proposed project is evaluated to see whether or not the study meets appropriate definitions of study requirements and whether the study design meets the minimum requirements to produce definitive and useful results.

A third basis of evaluation of the projects deals with technical and management competence of the researchers. In this regard, an analysis is made to determine the capability and experience of the researchers to handle the level of complexity involved in the study and to determine whether the total staff requirements, time duration, and phasing of the study are adequate.

An example of programming by committee is that of the NCHRP. NCHRP funding is based on the allocation by the individual State highway department of approximately one-twentieth of the Federal-aid highway planning research monies, which yields an annual program budget of approximately $3 million. Projects or problem areas for NCHRP are solicited from the Federal Highway Administration, chief administrative officers of AASHO member departments, chairmen of AASHO committees, and members of the executive committee of AASHO. Administrative decisions are then made on the basis of this committee action.

Program Execution

Manpower availability must be considered in the programming of any major research effort. The ultimate success of any research program in terms of both numbers and proficiency is dependent on the adequacy of the research staff which can direct its efforts to the research program. In the field of highway transportation, three basic sources of manpower have been utilized to carry out the program—in-house staffs, universities, and private organizations.

The in-house programs offer a variety of advantages in that they permit close coordination and control of the researcher by the sponsoring agency. They permit development of special competence in staff personnel and the continuing availability of this competence over a long period of employment. They permit acquisition of specialized equipment and facilities for continuing research in a given area and they permit those administering the research program to maintain close contact with the actual performance of research work. In-house research by Federal agencies (such as the BPR) and by State highway departments has been and will likely continue to be a significant part of the total research effort.

Many colleges and universities have close working relationships with their State highway departments, often involving joint research committees or councils responsible for much of the research effort. University research can offer advantages in that it often permits the research project to draw upon the talents of individuals whose educational backgrounds and qualifications are more diverse than those available on a full-time basis with the State highway departments. University research also provides for enlistment of graduate students in the research effort and often leads to attraction of competent students to the field of highway transportation as a permanent career.

A growing capability to perform transportation research is developing in the private sector of industry through research foundations, institutes, and consultants. These organizations are generally more flexible in their ability to staff research projects and they can bring together expert capabilities for concentrated efforts on a research program.

As discussed in this chapter, the literature search, interviews and symposium at Saratoga Springs suggested research projects and problems, as well as approaches to research structuring, and indicated some of the present difficulties in research administration. The succeeding chapters propose a workable framework about which to organize research projects and suggest methods for establishing priorities and estimating costs.

CHAPTER FIVE

TRANSPORTATION RESEARCH FRAMEWORK

The previous chapters have devoted considerable discussion to the identification of the agencies and activities that currently comprise the highway transportation research program. A review of these agencies and activities leads to several pertinent conclusions, as follows:

1. There is no single spokesman or agency identifying goals and objectives, or directing the effort of transportation research in the nation.
2. There may be some duplication of effort by individual States, by the several Federal agencies involved in the transportation field, and by other public or private research agencies.
3. There has been an undesirable fragmentation of the all-too-limited research effort. Many projects have been short-term with limited and often inadequate funding.
4. Research findings often have not been subject to an effective, planned program of interpretation and application.

As a consequence of these weaknesses in current transportation research efforts, it has been difficult to demonstrate the benefits and values of the research effort, and financial support for the research program has continued to be inadequate. The research effort continues to be scattered, lacking a central focus, and has an element of competition rather than coordination developing among various research agencies. This fragmentation and internal turbulence has presumably hampered progress and jeopardized the needed funding support. With the creation of the U. S. Department of Transportation, coordination of Federal research efforts for highways should be improved. Nevertheless, an organized and systematized procedure and structure is needed through which the entire effort by highway agencies may be managed and coordinated with continuity and clarity toward defined goals.

NATIONAL TRANSPORTATION RESEARCH GOALS

To help achieve this coordination, it is important to recognize several national transportation research goals. Highway transportation research efforts obviously must be an integral part of these national transportation research efforts and can achieve this integration only through prior recognition of these goals. As an outgrowth of this study, and specifically as a result of the symposium and the staff interviews, three national transportation research goals were recognized, as follows:

1. To serve national commerce and defense by optimizing the development and function of an integrated national transportation system.
2. To improve national, regional and community development through development of optimum transportation service and integration of the transportation facilities with the community.
3. To foster national health and welfare as affected by transportation, through (a) increased safety and convenience; (b) reduction of air and water pollution, and noise abatement; and (c) improved well-being of users and nonusers of transport facilities.

These national goals obviously span the interests of known and potential transportation modes, and all agencies and communities. They offer common objectives toward which all transportation research efforts of the nation can strive, and against which individual research programs can be objectively measured. Therefore, it is important that research agencies recognize and accept national goals and program their efforts accordingly.

HIGHWAY TRANSPORTATION RESEARCH GOALS

As a subsequent step in developing a structure for State-supported highway transportation research, it is also desirable that objectives specifically applicable to highway transportation—derived from the national transportation goals—be recognized and identified. The in-depth discussions held during the course of the project with key highway officials provided the means to identify the following three highway transportation research goals applicable to the research structure:

1. *To improve highway planning, design and construction as a part of an integrated transportation system.*—With the growth of integrated national transportation systems dramatically emphasized through the Federal and State agencies, no meaningful objective relative to the improvement of highway transportation can be established without consideration of the role of highway transportation in the integration. This first goal suggests research dealing with the technological advancement of the highway transportation system to complement advancement in other transportation modes as contributory to a total system concept. To this end, highway planning, design, construction and operation must be improved, and their management made more coordinated.

2. *To improve the role of highway transportation in optimizing land use and urban development by improving the safety, serviceability and operations of the present highway system.*—Growing recognition of the interactions between highway travel and land development, the increasing demand for multiple use of available land areas, and the complex assessment of jurisdictions and responsibilities in development of community integrated highway facilities, all represent major challenges. New concepts in structural and geometric design, in maintenance and operations, in types and levels of service, and in construction materials will be required if the highway is to serve successfully in optimizing land use and urban development. The research need now apparent is that required to locate, design and construct highway facilities in the complex urban locations where road and street congestion seriously reduces the utility of motor transportation. Also needed is research into techniques to integrate a high standard of highway facilities with urban property uses so that mobility can be continued without reduction in environmental values which attract people to cities. Such urban design must consider parking and terminal requirements, advance planning and property acquisition, relocation of persons affected by construction, multiple uses of rights-of-way, and new highway concepts integrated with existing systems to serve potential new types of vehicles. The complexities of design must be studied to optimize the utility of urban highways.

3. *To foster the integration of the highway with the community through improved identification and quantification of sociological, political, economic, and aesthetic factors in highway transportation.*—The definition of problem areas in the administration and financing of transportation improvements will need careful attention as urbanization spreads and intensifies, creating the need for solutions which transcend existing lines of political jurisdiction. Integration of the highway with the community residents must be improved. Aesthetic design and the use of highways to enhance or preserve roadside development must be achieved.

Financial and administrative responsibilities may require redefinition in the light of changing social requirements, the development of new transportation concepts, and growing recognition of the interactions between highway travel and policies on such matters as land development, off-street parking, mass transit, and vehicle ownership and use. New sources of funds for financing the construction and operation of future transportation systems, or at least new approaches to the problem of allocating funds from existing sources, may have to be found. The rationalization of transportation responsibilities, particularly in urban areas and regions, appears to be fundamental to the search for solutions to such problems.

Economic analyses of alternatives, particularly those involving different transportation modes, are still limited in scope. It may be more important to improve the ability to evaluate the results of traffic forecasts and assignments than to improve present techniques for developing these estimates. At present, it is not possible to quantify all the costs and benefits satisfactorily, particularly those which relate to society in general rather than the road user specifically. Even customary approaches to estimating road-user costs and benefits are suspect. Better and more sophisticated methods are needed—methods which include non-user elements along a broad spectrum rather than merely user elements. The need for better tools to determine the comparative desirability of alternative transportation modes or alternatives in terms of modal "balance" in urban areas is evident.

POLICY GUIDANCE FOR HIGHWAY TRANSPORTATION RESEARCH

To utilize best the efforts made in the field of highway research, and to make those efforts a coordinated part of an enlightened transportation research program, it is desirable that the highway transportation research goals be promoted as those toward which all research in this field will be focused. With these goals as objectives, highway research in general will have a cohesiveness and focus to ensure its compatibility and direction; automatically there can be a coordinated national research effort in the field of highway transportation.

Although subject to periodic revision, these transportation and highway goals will change very slowly with time. Because of their interrelationships, the highway goals will be affected as the national transportation goals shift or change, but the broad context in which they are framed should not react to short-range influences and a continuity of direction and purpose should be assured over many years. It is important that highway research not be unduly distorted or disturbed by the many short-range innovations and ideas that seem to characterize highway transportation. Although new ideas and concepts have their value and must be properly considered, they should not be allowed to fragment the more comprehensive and broader goals. Rather, the total program should be capable of absorbing and profiting from such innovations in proportion to proven values and needs.

PROBLEM AREA IDENTIFICATION

Within each of the three proposed highway transportation research goals, major problem areas can be defined that can be utilized to guide and structure the research program. Problem areas are so named to identify major areas of related research activities that lead to the selection of specific projects focused on the overall goals. Thus, these problem areas are relatively broad in scope and are responsive to research trends.

These problem areas will necessarily change as economic and technological advances are realized in transportation systems, and as political and sociological influences are felt in the administration of research efforts. Therefore, the

TABLE 9

HIGHWAY TRANSPORTATION RESEARCH GOALS AND RELATED PROBLEM AREAS

HTR GOAL	RELATED PROBLEM AREAS
1. To improve highway planning, design and construction as part of an integrated transportation system	1. Quality control of highway construction 2. Design and construction criteria for the accommodation of maintenance 3. Standards for relating levels of service on freeways to economic and land-use considerations 4. Determination of sizes, weights, and performance requirements (limits) for highway vehicles 5. Concepts and criteria for the integration of highways with other modes in the total transportation system
2. To improve the role of highway transportation in optimizing land use and urban development by improving the safety, serviceability and operations of the present highway system	1. Accommodation or reduction of obstructive highway appurtenances 2. Utilization of existing streets and highways to their maximum capability 3. Operation of streets and highways during nighttime and poor visibility periods 4. Development of maintenance techniques and equipment compatible with operating requirements on high-speed expressways 5. Surveillance and control of traffic flow on urban street and highway systems
3. To foster the integration of the highway with the community through improved identification and quantification of sociological, political, economic and aesthetic factors in highway transportation	1. Aesthetic considerations in the design, maintenance, and operation of highways 2. Impact of various types of highway design features upon environmental values 3. Accommodation of multiple use of right-of-way in urban areas

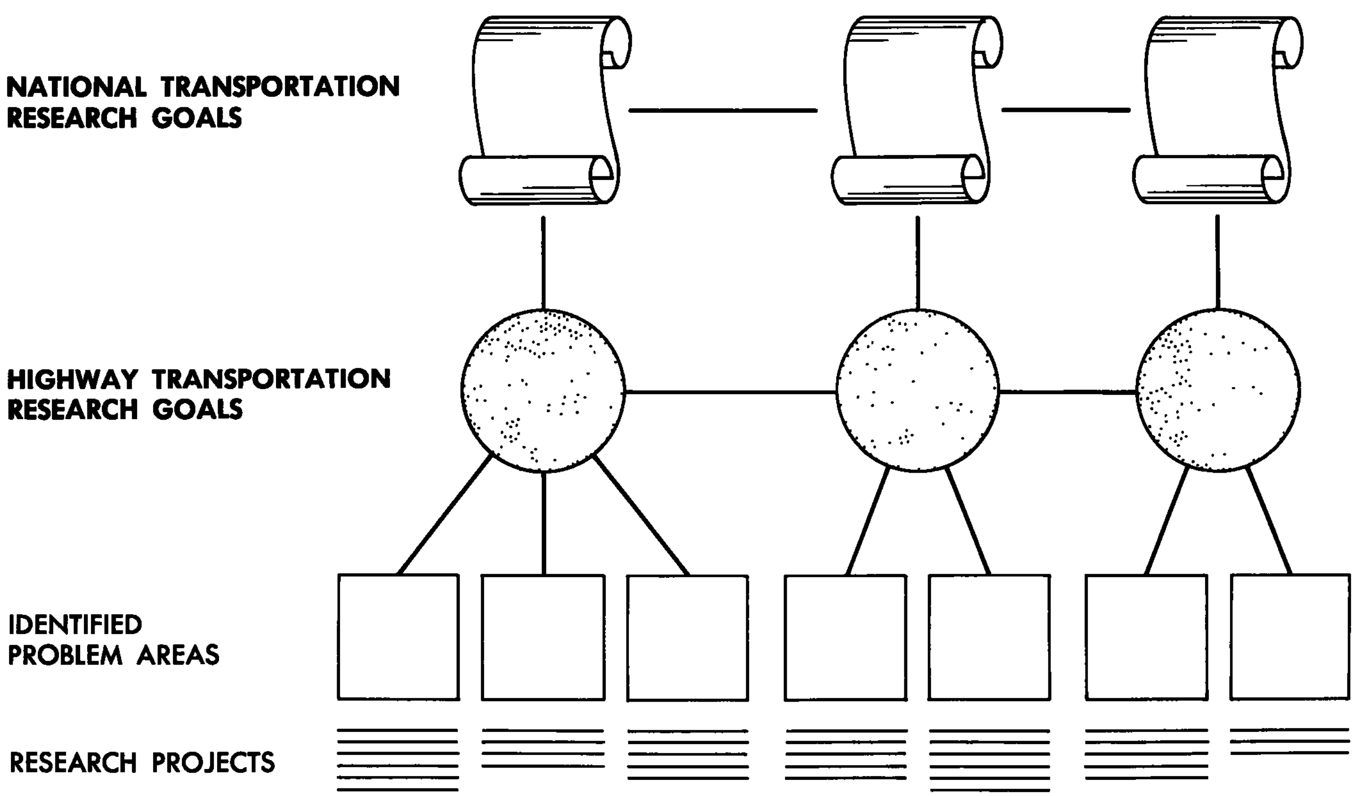

Figure 5. Framework for highway research structure.

identification of problem areas should be updated periodically, perhaps on an annual basis, and program flexibility which permits this revision is considered highly desirable. This updating will ensure that the problem areas are current yet continue to recognize the long-term aspects of those elements that require continuity and longer periods of time.

In this connection, the information and discussion developed through the interviews, the Saratoga Symposium, internal staff conferences, and the detailed review of literature and publications dealing with highway transportation research needs, pointed up 13 significant problem areas which are proposed for current and major consideration in the development of the national highway research programs (a description of each problem area is given in Appendix B). These problem areas are logically assigned to one of the three overall highway research goals as indicated in Table 9.

The goals and problem areas provide a framework for the organization and management of research and become the basis for a mechanism and technique for the orderly structuring of highway transportation research recommended in Chapter Seven. Figure 5 shows the interrelationships among goals, problem areas, and the individual research projects.

CHAPTER SIX

RESEARCH FUNDING AND PROJECT PRIORITIES

Essential to the sound organization of any research effort is the estimation of expected costs and the establishment of priorities for the work to be accomplished. In both of these areas—cost estimating and priority rating—investigation has generally shown that highway research lacks a unified approach or system, thus receiving a lower level of funding support than may be otherwise available.

Particularly absent, under current procedures, is an indication of the desired level of funding that should be expended on highway research and the rationale that would influence management to support such a level of expenditure. Identification of financial needs is fundamental to any structuring process. Therefore, this chapter provides general remarks about research funding and the selection of project priorities.

TRENDS IN FUNDING HIGHWAY RESEARCH

Required levels of funding are best developed following an appraisal of desired research problems and the estimation of individual project costs. Comparisons of various statistics in highway transportation are also of interest and use in assessing trends and in evaluating research-oriented programs in the United States. Available data in this area are given in Table 10, which can be used to evaluate previous expenditures and draw inferences for future applications. Information on highway research supported by State-appropriated funds was not available from all States. Of the eleven States questioned, eight relied entirely on Federal-aid funds and three spent a minor amount of their own funds for State research projects.

Comparing data for about a 10-year span between 1955 and 1964, the nation's population increased 16 percent: road and street mileage, 7 percent; and vehicles, 37 percent. Thus, the number of registered vehicles increased five times faster than roadway mileage and more than twice as fast as the population. In this same decade, the gross national product increased by 58 percent and the amount of funds spent on highway construction and maintenance by 46 percent. In the same period, total research and development expenditures in the United States tripled.

For highway research, total funds expended annually increased from about $17.8 million in 1958 to $35.7 million in 1965, a growth of 100 percent in seven years. Federal sources provided about four-fifths of the 1965 expenditures.

An appraisal of the effort being devoted to highway transportation research was indicated in testimony before the Congressional Committee on U. S. Government Operations conducted in January 1966. Federal urban transportation research and development expenditures for fiscal year 1966 were reported to total $24,200,000. For roads and highways, including bus transportation, the 1966 urban research and development program of the U. S. Bureau of Public Roads amounted to $14,000,000, and that of the Department of Housing and Urban Development (HUD) totaled $3,800,000. The 1966 HUD research program for surface rail and subway transportation was $5,400,000 and for other forms of transport $1,000,000.

In the testimony, analyses were presented of the magnitude of effort involved in several individual highway research studies as measured by funding. Of the projects for which funding data were given, Table 11 shows that approximately two-thirds cost less than $20,000 each per year. The "average" highway research project, among the 1,500 tabulated, involved current costs of $24,000 and a total budget of $78,000, with the average duration of study extending over three years. These figures show the limited scope of highway research projects and underscore the need for substantial increases in the total research effort.

TABLE 10

HIGHWAY DATA AND RELATED STATISTICS; UNITED STATES, 1955-1965 (all values in millions)

ITEM	1965	1964	1962	1960	1958	1955	INCREASE, 1955 TO 1964 (%)
1. Population	195	192	187	184	175	166	16
2. Miles of roads and streets	3.69	3.64	3.6	3.54	3.48	3.42	7
3. Registered vehicles	90.4	86.3	79.2	73.9	68.3	62.7	37
4. Motor vehicle-miles	888,000	847,000	767,000	719,000	665,000	608,000	40
5. Gross national product ($)	676,000	629,000	560,000	504,000	437,000	398,000	58
6. Total nat. research expend. ($)		18,800	15,480	13,600	10,800	6,200	200
7. Highway constr. and maint. ($):							
State-administered	—	7,300	6,200	5,600	6,300	—	
All highways	14,200	10,800	9,500	10,100	7,800	7,400	46
8. Highway research ($):	35.7	—	—	—	17.8	—	
Bur. of Public Roads ($)	6.1	4.4	3.4	3.6	2.3	—	
Federal-aid to States ($)	25.5	20.8	9.6	—	4.7	—	
State funds ($)	4.1	—	—	—	5.0		
University funds ($)	—	—	—	—	1.5	—	
AASHO Road Test ($)	—	—	—	—	4.3	—	
9. NCHRP ($) [a]	2.5	1.9	1.2	—	—	—	
10. Highway fatality rate [b]	0.049	0.047	0.041	0.038	0.037	0.038	24
11. Highway accident rate [b]	—	12.3	11.0	10.4	10.0	9.9	24
12. Highway accident costs ($)	—	8,100	7,300	6,500	5,600	4,500	81
13. Motor vehicle wholesale value ($)	22,300	18,061	15,700	14,500	9,470	14,500	25

[a] Included in item 8.
[b] Per million vehicle-miles of travel.

Funding in Perspective

In 1965 only 0.25 percent of highway funds ($35.7 million out of $14,200 million) was devoted to research, although 3.0 percent of the gross national product was spent on research and development (Fig. 6). By contrast, in 1963, in the automotive field 4.7 percent of the manufacturers' wholesale sales receipts were used in research and developmen. In the Department of Defense, 12.4 percent of the 1965 budget was spent on research, development, testing, and engineering.

Highway research funds appear grossly inadequate when related to the vital importance of highway transportation. Only conjecture supports the premise that highway transportation has maintained its place in the growth of the economy. Certainly the role and potential of the highway has not been exhausted; indeed, the large and growing annual expenditures for maintenance and the funds required for new facilities seem to demand a higher maxi-

TABLE 11

COST OF HIGHWAY RESEARCH PROJECTS [a]

PROJECT COST RANGE	CURRENT YEAR, 1966 NO. OF PROJECTS	CURRENT YEAR, 1966 %	OVERALL PROJECT NO. OF PROJECTS	OVERALL PROJECT %
Under $5,000	389	25.9	105	7.3
$ 5,000 to $ 10,000	274	18.3	162	11.3
$ 10,000 to $ 20,000	328	21.8	215	15.0
$ 20,000 to $ 50,000	361	24.0	383	26.7
$ 50,000 to $100,000	107	7.1	267	18.6
$100,000 to $250,000	36	2.4	191	13.3
Over $250,000	7	0.5	111	7.8
Reports with cost data	1,502	100.0	1,434	100.0
Reports without cost data	1,537	—	1,605	—
Total reports	3,039	—	3,039	—

[a] Source: Highway Research Information Service, letter of Dec. 2, 1966, based on progress reports from U. S. agencies as of Dec. 1, 1966.

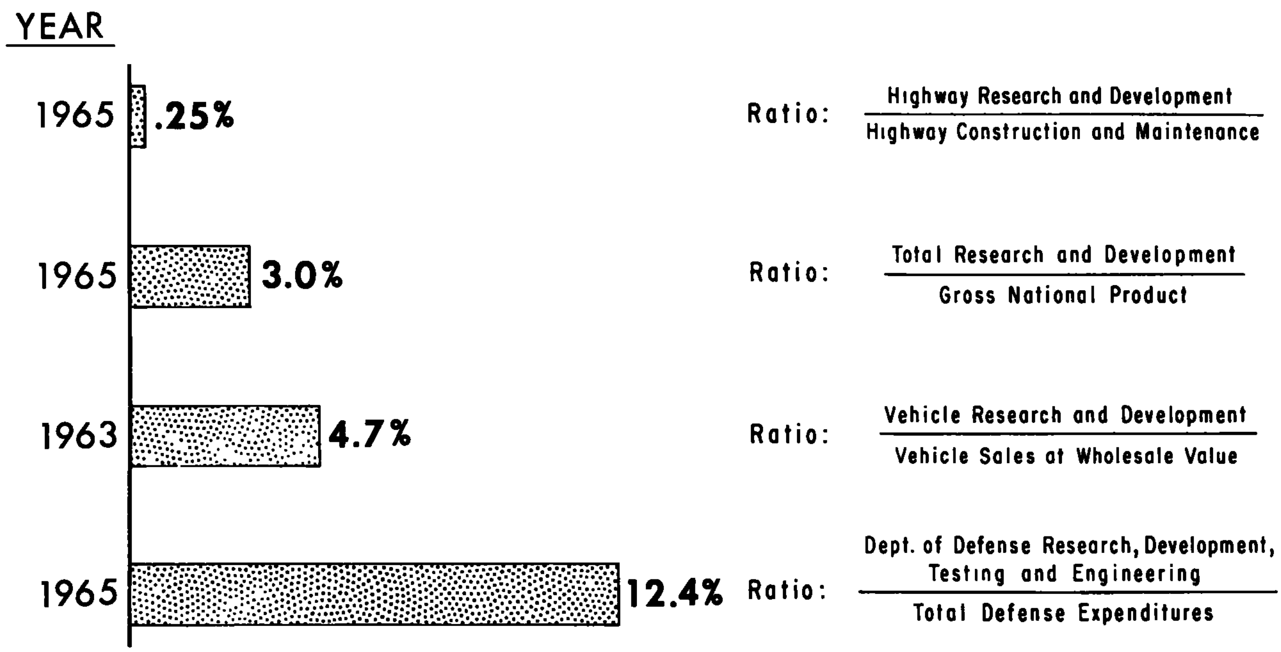

Figure 6. Comparison of U.S. research efforts.

mum return on the investment. (It is appropriate here to note that early sections of the Interstate System will be requiring extensive maintenance soon. This need will require substantial research to minimize costs and this aspect has been identified as a major problem area.)

The high percentage of Federal funds expended, compared with that from other sources, indicates a need for organization and procedure directed at increasing the expenditures by the other sources, as well as the development of new fund sources. A system wherein highway research efforts can be focused through identification of major problem areas will be helpful, as contrasted with isolated action on an array of projects. An organized and structured approach will also help to foster interest and positive funding support from industry and private organizations, as well as encourage added financial programming from government.

ESTIMATING RESEARCH COSTS

Accurate cost estimating of research and development projects for budgeting purposes is dependent on the adequacy of definition for proposed projects. If the details of a planned project are clearly developed, labor, equipment, and material costs can be estimated better, and a reasonable degree of confidence can be assigned to the cost estimate. At the other extreme, where the problem is ill-defined, proper cost values are not obtainable. Inasmuch as research projects, by their very nature, usually delve into the unknown, their cost estimates fall into the lower end of the confidence scale.

Research project definition, in as much detail as possible, is of utmost importance. The character and objectives of the specific tasks and subsequent working procedures should be as clear as possible. Various methods with which to estimate such costs have been developed over the years, and all require sound professional judgment in their application.

Highway research projects vary from paper analyses to those requiring a great deal of laboratory investigation with attendant equipment costs. Some projects may involve the building of prototypes or the development of unique and expensive equipment; still others may require collection of voluminous field data. The statement of the scope of the work should clearly indicate the extent of research or reporting to be completed in the particular project.

In much of the nation's highway research, once a program budget is set, administrative formalities to obtain additional funds are usually formidable. Consequently, the research effort actually expended is often not necessarily that which is needed to solve the problem, but the work tends to contract or expand to fit the preestablished budget figure. This is an additional reason for realistic budget figures to be established initially and it is suggested, therefore, that all research proposals include an estimate of the professional man-months required.

One cost approach that has been extensively used and generally found adequate is the "dollars-per-man" assumption. In this method a knowledgeable researcher estimates the amount of professional time required to complete the proposed scope of work. This value is then multiplied by an empirical rate to obtain the project cost. Current rates run from $27,000 to $40,000 per man-year. As with all rules-of-thumb, however, such unit values must be applied with caution, because time estimates can be overly optimistic. This unit cost must obviously include the costs of travel, equipment, all subprofessional activities, and research overhead items.

To help formulate a reasonable unit cost, data on professional man-hours for 48 completed projects were subjected to a cost analysis. These 48 NCHRP projects, finished prior to January 1967 and selected for completeness of cost data, were analyzed through the cooperation of the business office of the National Academy of Sciences. The calculations revealed a direct relationship between total project costs and professional man-days involved. This analysis showed that each professional man-month of effort cost approximately $3,000, with a minimum "project initiation" cost of $25,000. For this report, therefore, costs of proposed research projects were estimated as follows:

$$\text{Total cost} = \$3{,}000 \times \text{Prof. man-months} + \$25{,}000$$

In actual application, the values may be altered to reflect better cost information or to recognize unusual capital equipment outlays or other project expenses.

PROJECT PRIORITY SYSTEM

There probably never will be sufficient funds to finance all proposed research projects, or even all worthwhile projects. Highway transportation research has been notoriously poorly funded and is likely to remain so for some time, even with improved programming procedures. Consequently, to obtain the most beneficial use of available highway research funds a priority system must be established to guide the selection of projects.

As indicated in Chapter Five, a necessary policy decision in the selection of proposed research projects is the assignment of priorities to each major problem area that forms the basis for a research program. These priorities would be reviewed periodically for appropriateness. The priorities for individual projects should then be coordinated with those for the problem areas. Obviously, projects whose results are needed before other projects can be started must have the highest priority, but a general plan is also needed.

Types of Priority Systems

In industry, motivated by profit, a number of formulas exist for project ranking. In each of these methods the formulas include such elements as estimated unit sales per year, profit per unit, unit sales price, percent of chance of commercial success, net earnings over the life of the product, and the time value of money. The techniques include index of return, square-root-life, profitability, and calculated-risk methods, as described by Seiler (*10*). These industry methods obviously are designed to be useful where profit and sales are dominant considerations and are therefore limited in their application.

In the public domain, such as highway transportation research, none of the industrial methods appears particularly appropriate, because there is no comparable profit motive or measure and instead there is the added intangible of "the public interest and welfare." What is needed in the public interest may have no relation to cost, may be cheap or inexpensive to achieve, may be quickly achieveable or require an extended period of time, or may serve a few or many. The point is, a judgmental determination is required, based not on economics or tangible results alone but on a managerial overview of experience. Thus, reasoned appraisal appears to be the most appropriate way to present priorities for highway research.

To have a well-ordered program of highway research, some form of "cost-benefit" analysis might be attempted. It appears that a logical system would be to arrange projects in the order of magnitude of their likely payoff, where,

$$\text{Payoff} = \text{Prob. of success} \times \text{Potential benefits} - \text{Research costs}$$

Benefits, among others, would be cost savings in construction, maintenance, or operation of highways, and the value of such intangibles as safety, aesthetics, comfort, convenience, or time saved in travel. For uniformity in evaluating projects, implementing instructions should be prepared for those factors. They would include such items as time over which to consider savings, various highway statistics, and dollar values to be assigned to the intangibles (e.g., the dollar value of a life saved).

The one advantage of such a formula is that it places all priorities on the same footing except for differences between individuals' professional judgment in assessing the various factors of the equation. It should be noted, however, that there is an element of judgment in each of the factors. First, the probability of success must normally be estimated by the administrator. Second, benefits must be estimated in dollars. (If the benefits are intangible, a a judgment is again required in setting a value on the benefits.) Third, the cost of the research must be estimated and the more basic the research the more judgment that must be used in estimating costs. With an exercise in judgment entering each factor it is questionable whether it is better to use such an expression or to arrange the projects in order of priority intuitively without benefit of such a formula.

A method called "weighted limited decisions" would place values or weights on elements of a research structure. These values can be assigned by one or more qualified analysts as a result of a judgmental rating of the intrinsic worth of the element, and its relative worth in the whole research structure. This last method is deemed most practical for establishing highway research project priorities. As a result, the priority schedule established for the illustrative research program (see Appendix D) utilizes the weighted-limited-decision approach.

CHAPTER SEVEN

RECOMMENDED PROCEDURES FOR STRUCTURING HIGHWAY TRANSPORTATION RESEARCH

In Chapter Five, highway research goals and current major problem areas within each goal were identified by this research project staff based on the interviews, the symposium, and the staff conferences held throughout the study. This arrangement of research into goals and problem areas can be considered a framework around which the other elements of highway research can be organized.

It is recommended that these research goals and problem areas be reviewed and evaluated annually by highway administrators and that the resulting framework be formally approved and adopted by the administrators. It is also recommended that each problem area be assigned a priority value according to its relative importance under the appropriate goal. Numerical values of 3 for high priority, 2 for intermediate priority and 1 for low priority will permit subsequent processing of proposed projects in an efficient manner.

To fill out the framework and complete the research structure, it is necessary next to select from available sources research projects appropriate to the problem areas, assign priorities, and compute costs.

RESEARCH PROJECT SOURCES

As one major source of research projects there already existed at the beginning of this study, in the files of the Highway Research Board, more than 700 proposed research project statements compiled by the several committees of the Board, by the various State highway agencies, by the U.S. Bureau of Public Roads, and by other organizations and associations. During the course of the study 200 additional research proposals were developed or elicited from interviews and the symposium by the study staff.

It is recommended that this stockpile or library of proposed projects be continually enlarged by new proposals emanating from all sources. A fruitful source will continue to be the committees of the Highway Research Board and the research organizations of the member highway departments. As projects are selected for research, or are no longer appropriate, they should be removed from the active stockpile.

REVIEW AND CATALOGING OF PROJECTS

Each proposed project should first be reviewed by qualified staff experts for technical soundness and placed in a standardized format. Project costs should then be estimated.

Inasmuch as the HRIS classification system already exists for current and completed research, it is recommended that its use be extended to potential research projects. Subject area codes, key words, and an abstract should be prepared for each proposed project and the project entered into the HRIS classification system.

Thus there will exist at any given time a stockpile of technically sound, proposed research projects, properly classified and priced. This stockpile then will provide the resource from which projects can be drawn to flesh out the framework of research goals and problem areas.

PROJECT SELECTION AND ASSIGNMENT OF PRIORITIES

To simplify the selection of projects to be applied to the framework, a portion of the process can be mechanized through the use of the HRIS classification system. As an initial step, each selected problem area also should have assigned to it appropriate HRIS subject area codes. (Subject area codes for the currently identified problem areas discussed in Chapter Five were selected by members of the study staff, and are indicated in Appendix B. HRIS subject area codes are listed in Appendix C.) The assignment of these codes will be dependent, of course, on the full understanding of the problem area and the exercise of professional judgment in identifying the types of research projects that would yield the required effort to attack successfully the particular problem area.

The next step in the project selection process should be a machine matching and selection (by use of HRIS codes) of the projects by problem area.

Next, the appropriateness of the projects selected by the machine for the problem area should be determined through professional judgment by qualified staff experts. In this process, project statements may be rejected and the discards returned to the project stockpile, or projects may be combined or modified to suit the problem area. If apparent gaps exist in the list of projects applicable to the problem area, they should be identified at this time and additional research project statements prepared. Thus, a tailored list of projects applicable to the particular problem area will be developed.

The next step should be the assignment of a priority rating to each of the projects within the problem area. It is recommended that the staff experts assign a priority of high (3), intermediate (2), or low (1) to each of the selected projects, depending on the degree of importance of the project to the problem area.

With more than one problem area being considered in the structure, it is necessary to refine further the assignment of priorities. The project priority should be multiplied by the problem area priority to give a weighted priority to the project. Where a project appears in more than one problem area, the weighted project priorities should be added together to give a final composite priority value to that project. This system thus makes it possible to establish individual priority ratings for each of the proposed projects scattered among several problem areas.

The completed structure of proposed research then would consist of approved goals, subordinate problem areas, and properly screened and priced projects, listed under each problem area. A separate listing of projects by composite priority values should also be prepared to help in the selection of projects for a given research program.

It is recommended that the final selection, from the completed structure, of those projects to be undertaken in a given research program, be made by the highway administrators.

ADVANTAGES OF PROPOSED PROCEDURES

The foregoing procedure provides a simple and effective means of organizing an uncoordinated and voluminous collection of proposed research projects. It permits and facilitates a logical grouping of small individual projects into major long-range, problem-oriented research programs. This structuring process would be useful in programming research for NCHRP, as an example.

No substantial change in the current methods of obtaining proposed research project statements will be required to follow this structuring process. As project statements are developed by the Highway Research Board committees, AASHO member highway departments, or from other sources, they can be submitted to HRIS, where they will be edited, coded, priced, tabulated, and then included in appropriate problem areas as annual updating of the structure is accomplished.

The recommended structuring procedure provides a more effective means of research project statement development than does the current random method. With the major problem areas fully identified and analyzed, gaps in proposed research will become apparent, thus permitting additional project statements to be drafted to cover those phases of a problem area which appear to be omitted.

RECOMMENDATIONS FOR IMPLEMENTATION

In order to utilize the procedures developed in this study, it is recommended that AASHO formally adopt the concepts for structuring a research program outlined in this chapter. It is recommended that AASHO be responsible for the *administrative action* required to establish policy controls and to make annual program selections (Fig. 7).

It is further recommended that the Highway Research Board be retained as the agency responsible for implementation of these concepts and for the performance of the *staff action* required to build the research structure.

As a part of the Highway Research Board's duties, HRIS should establish and maintain a stockpile of proposed highway research projects, and should provide the annual

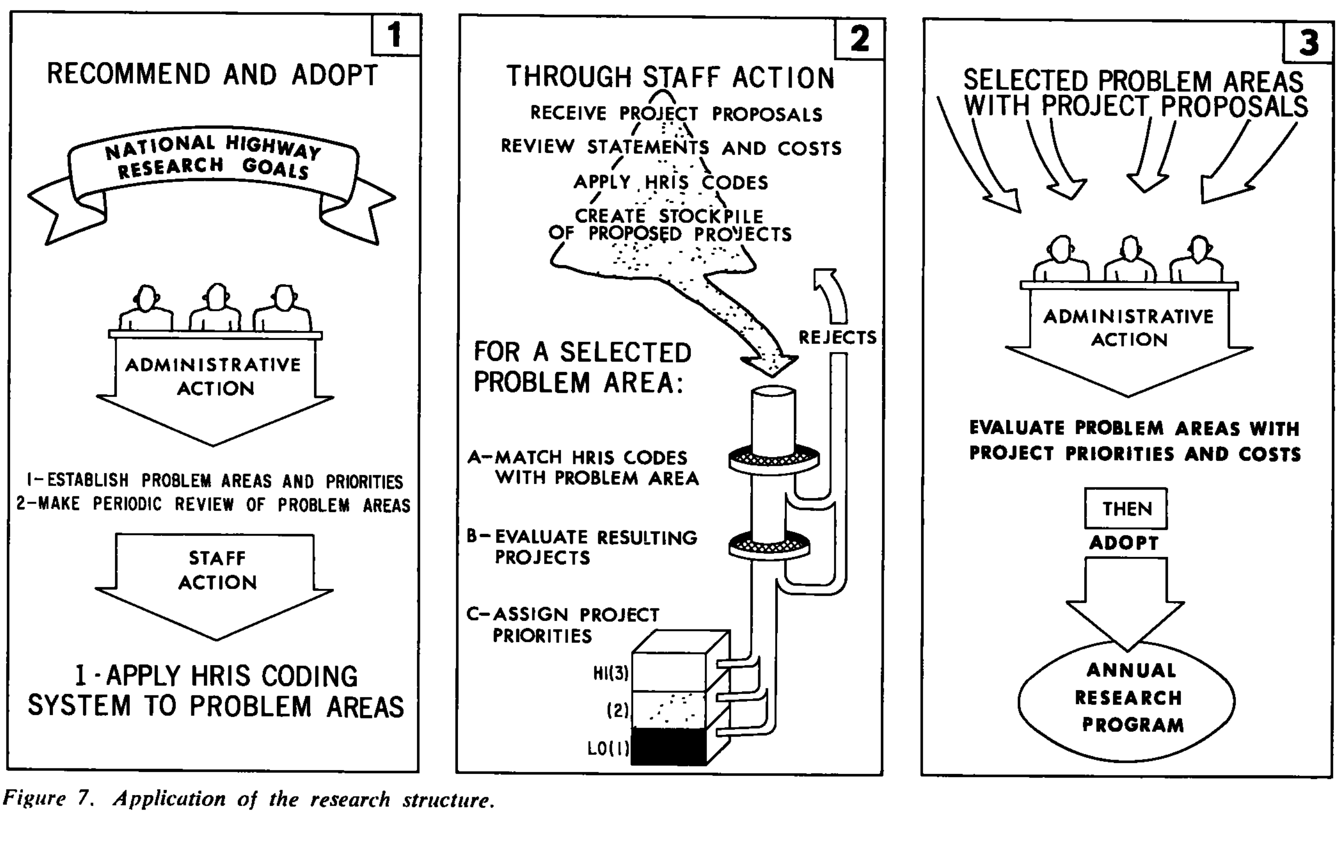

Figure 7. Application of the research structure.

screening, matching, and print-out of projects fitting the framework of goals and problem areas approved by AASHO.

HRB also should be requested to publish annually the resulting research structure as approved by AASHO, so that it might serve to guide and encourage research directed toward the same goals by NCHRP, AASHO member departments, and other agencies, and with other sources of funds beyond those provided through the highway departments.

REFERENCES

1. MICKLE, D. G., "The National Cooperative Highway Research Program. *Traffic Quart.*, Vol. 20, No. 4 (Oct. 1966) p. 494.
2. *Webster's Seventh New Collegiate Dictionary.* Merriam (1965).
3. *Highway Research in Progress.* HRB (Sept. 1965).
4. *Transportation and Parking for Tomorrow's Cities.* Prepared for the Automobile Manufacturers' Association by Wilbur Smith and Associates, New Haven, Conn. (1966).
5. "Highway Research in the United States." *HRB Spec. Rep. 55* (1959).
6. BAKER, R. F., "A National Program of Research and Development for Highway Transportation." Circ. memorandum from Director, Office of Research and Development, U.S. Bur. of Public Roads (Sept. 20, 1965), as revised.
7. "Public Works for the Future." Spec. Rep., Res. Proj. No. 110, Am. Pub. Works Assn. Research Foundation (Nov. 1963).
8. HANSON, W. B., and HARTLEY, D. K., "Proposal for a Program of A.I.P. Involvement in Planning Research." A committee report to Board of Governors, Amer. Inst. of Planners, p. 11 (Aug. 1964).
9. TRANSPORTATION ASSOCIATION OF AMERICA, "Major Transportation Policy Research Needs." Report of TAA Research Committee (Dec. 1965) 12 pp.
10. SEILER, R. E., *Improving the Effectiveness of Research and Development.* McGraw-Hill (1965).

APPENDIX A

SARATOGA SYMPOSIUM ATTENDANCE LIST[a]

OCTOBER 23-25, 1966

SARATOGA SPRINGS, N. Y.

Baker, Robert F.
Director of Research and Development
U. S. Bureau of Public Roads
1717 H Street, N. W.
Washington, D. C.

Barnett, Joseph
Executive Director
U. S. Bureau of Public Roads
Washington, D. C.

[a] Titles and addresses as of October 1966.

Byrd, L. G.
Bertram D. Tallamy Associates
1411 K Street, N. W.
Washington, D. C.

Carey, W. N., Jr.
Executive Director
Highway Research Board
National Academy of Sciences
2101 Constitution Avenue
Washington, D. C.

Carroll, J. Douglas
Director
Tri-State Transportation Study
100 Church Street, Room 1806
New York, N. Y.

Colley, Bertram E.
Manager
Paving Development Section
Portland Cement Association
Chicago, Ill.

Conrad, Paul E.
Wilbur Smith and Associates
495 Orange Street
New Haven, Conn.

DeLong, James
Transportation and Community Development
Department of Housing and Urban Development
Washington, D. C.

Gillespie, R. J.
General Motors Corporation
Broadway at 57th Street
New York, N. Y.

Goldenthal, A. J.
Ford Motor Company
Dearborn, Mich.

Goldstein, Leon G.
Chief, Research Branch
Division of Accident Prevention
U. S. Public Health Service
Arlington, Va.

Goodwin, W. A.
Program Director
National Cooperative Highway Research Program
2101 Constitution Avenue
Washington, D. C.

Gazis, Denos
International Business Machines
Yorktown Heights, N. Y.

Griffith, John M.
Director of Research and Development
The Asphalt Institute
University of Maryland
College Park, Md.

Hammond, Harold F.
President
Transportation Association of America
1101 17th Street, N. W.
Washington, D. C.

Healy, Kent
Professor of Transportation
Yale University
New Haven, Conn.

Hedlund, Robert C.
Research Department
Dow Corning Corporation
Midland, Mich.

Holmes, Edward H.
Director of Planning
Office of Highway Planning
U. S. Bureau of Public Roads
1717 H Street, N. W.
Washington, D. C.

Hooper, Curtis J.
Wilbur Smith and Associates
495 Orange Street
New Haven, Conn.

Hoyt, Homer
President
Homer Hoyt Associates
3939 Van Ness, N. W.
Washington, D. C.

Kerkering, John H.
Bertram D. Tallamy Associates
1411 K Street, N. W.
Washington, D. C.

Klauder, Louis
Klauder Associates
Philadelphia National Bank Building
Philadelphia, Pa.

Levinson, Herbert S.
Wilbur Smith and Associates
495 Orange Street
New Haven, Conn.

MacDonald, George E.
Bertram D. Tallamy Associates
181 Hillside Avenue
Williston Park, L. I., N. Y.

McAlpin, George W.
Deputy Chief Engineer
Technical Services
New York Department of Public Works
Albany, N. Y.

McMorran, J. Burch
Superintendent
New York Department of Public Works
Albany, N. Y.

Mickle, D. Grant
Vice President
Automotive Safety Foundation
Ring Building
Washington, D. C.

Morf, Theodore F.
Deputy Chief Highway Engineer
Illinois Division of Highways
Springfield, Ill.

Pendleton, William
Coordinator of Safety
Ford Foundation
477 Madison Avenue
New York, N. Y.

Poertner, Herbert G.
Director of Research
American Public Works Association
1313 E. 60th Street
Chicago, Ill.

Roos, Daniel
Department of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Mass.

Schlaefli, Jack
Stanford Research Institute
Palo Alto, Calif.

Schwar, Johannes F.
Director, Transportation Engineering Center
Engineering Experimental Station
Ohio State University
Columbus, Ohio

Shearer, Walker
Director of Highway Laboratory
Dow Chemical Company
1801 Building
Midland, Mich.

Smith, Larry
Larry Smith & Company
Suite 1750
420 Lexington Avenue
New York, N. Y.

Smith, Wilbur S.
Wilbur Smith and Associates
495 Orange Street
New Haven, Conn.

Stevens, David R.
Chairman
Maine State Highway Commission
Augusta, Me.

Swanson, John A.
Regional Engineer
U. S. Bureau of Public Roads
Delmar, N. Y.

Tallamy, B. D.
Bertram D. Tallamy Associates
1411 K Street, N. W.
Washington, D. C.

Taylor, Don C.
Assistant Secretary
American Society of Civil Engineers
345 East 47th St.
New York, N. Y.

Thomas, C. M.
Colorado State University
Fort Collins, Colo.

Thomas, Edwin N.
Director of Research
Transportation Center
Northwestern University
Evanston, Ill.

Wetzel, Edward
Engineer, Transportation Policy
Port of New York Authority
111 8th Avenue
New York, N. Y.

Woods, Kenneth B.
Goss Professor of Engineering
School of Civil Engineering
Purdue University
Lafayette, Ind.

APPENDIX B

PROBLEM AREA STATEMENTS

Note: Priority assigned by the study staff is given, as well as HRIS subject area codes (see Appendix C).

Problem Area 1-1

Quality Control of Highway Construction

Along with advances in design, materials and construction, rapid, reliable and applicable tests are needed so that highway organizations are assured they are getting the product that has been planned, specified and financed. Inspection costs for both materials and construction continue to rise, while applicability of some tests in modern construction programs is questioned. As demands increase for additional construction and improved quality, testing techniques must keep pace in economy, accuracy and scope. For example, testing of heterogenous materials such as concrete, asphaltic mixes, and soils may respond to statistical sampling. Other materials may require a more mechanized procedure to accelerate the testing time.

Objectives:

1. To develop new control and testing techniques and equipment to meet more demanding requirements for measuring quality of highway materials and construction.
2. To develop standard procedures for testing, and ap-

propriate specifications for materials and construction incorporating the techniques and equipment in Objective 1.

Priority: 1 (low)

HRIS Subject Areas:

23	31	40	61
25	32	41	62
26	33		64
	34		

Problem Area 1-2

Design and Construction Criteria for the Accommodation of Maintenance

Highway design must minimize maintenance requirements and must provide for the safe, efficient performance of the maintenance work that remains. Maintenance expenditures over the life of a project can be greater than the original cost, and accident losses to maintenance workers and highway users can be excessive where inadequate consideration of maintenance requirements is given in design. Criteria must be developed which will assist designers in producing limited maintenance requirements and "built-in" maintenance aids. Typical examples would be the selection of materials that require little or no painting; paving of inaccessible areas where turf maintenance would be costly and unsafe; interchange designs that ease the removal and disposal of snow and ice; landscaping and placement of structures, appurtenances, and plantings in or along the right-of-way to permit machine rather than hand mowing; and improved access to substructure components.

Objectives:

1. To prepare design criteria that will omit or reduce the necessity for future maintenance expenditures.
2. To develop designs that will permit required future maintenance operations to be accomplished safely, efficiently, and economically.

Priority: 2 (intermediate)

HRIS Subject Areas:

23	40	51	64
27	41	53	
		54	
		55	

Problem Area 1-3

Standards for Relating Levels of Service on Freeways to Economic and Land-Use Considerations

Planners and designers have inadequate criteria, and no simple formulas or standards, to determine what levels of service are economically sound to provide for freeways, taking into account other uses for the land, travel demands and environmental considerations. Guides should be prepared on the geometry of freeways for different service levels, specifically the number and reversibility of lanes; collector and distributor lanes; acceleration and deceleration lanes; the number, complexity, and types of interchanges; and such roadside services as communications and rest areas. Information on which to base such decisions is often intangible or is costly and involved to obtain. Nevertheless, the standards should be economically sound and in urban areas, where land is scarce and costly, the benefits to be derived from increased service must be carefully weighed against the loss of land for other uses.

Objective:

1. To establish guidelines for determining economical levels of service for freeways.

Priority: 3 (high)

HRIS Subject Areas:

15	22	52	83
		53	
		54	
		55	

Problem Area 1-4

Determination of Sizes, Weights, and Performance Requirements (Limits) for Highway Vehicles

The vehicle and the roadway must be compatible. To satisfy operating requirements of the vehicle the highway designer must know what these vehicle characteristics are. If characteristics are permitted to change constantly, the designed economic life of highways can be adversely affected. Therefore, uniform limits are needed on size, weight, configuration and other vehicle specifications to ensure compatibility with foreseeable developments in roadway technology. At the same time, the rapidly growing technological capability to increase structural and operating characteristics of highway vehicles strains at arbitrary limitations. Thus, criteria or guidelines are needed which assure the safety and proper service life of the existing highways and structures while accommodating all possible advances in the interest of the national economic growth.

Objective:

1. To determine practical guidelines within which the sizes, weights and performance of highway vehicles and highway design elements can be coordinated for efficient and economic evaluation.

Priority: 1 (low)

HRIS Subject Areas:

27	31	40	51
			52
			55

Problem Area 1-5

Concepts and Criteria for the Integration of Highways with Other Modes in the Total Transportation System

Broader concepts and criteria are needed for short- and long-range planning so that highways may best be integrated with and serve other modes of transportation. These standards would be focused on the efficient and safe transfer, where necessary, of people and goods from one mode to another, especially in urban areas. A systemwide approach is needed so that the interactions are identified and studied for their effect on the systems.

Objectives:

1. To develop concepts and criteria for the integration of highways with other modes in the total transportation system.
2. To solve interface problems between highways and other modes of transportation.
3. To establish warrants and other decision guides where alternate transportation modes or combined modes are being selected.

Priority: 3 (high)

HRIS Subject Areas:

11	22	55	81	90
			82	
			84	

Problem Area 2-1

Accommodation or Reduction of Obstructive Highway Appurtenances

In recent years the percentage of single-car collisions with highway obstacles such as light and sign standards, piers and guardrails within the right-of-way has risen considerably. This increase has occurred in spite of higher vehicle standards and better highway design geometry, or perhaps because of greater vehicle capabilities. A need therefore exists preferably to eliminate these obstacles from the right-of-way, or at least to reduce their hazard through design or locational standards.

Objective:

1. To establish highway design standards which will reduce accidents by accommodation or reduction of obstructive appurtenances within the right-of-way.

Priority: 2 (intermediate)

HRIS Subject Areas:

22	53
24	
27	

Problem Area 2-2

Utilization of Existing Streets and Highways to Their Maximum Capability

In many cities during peak hours, arterial streets and highways, and even newly constructed freeways, are choked with traffic. Because of the continuing increase in urban traffic, a need exists to find ways of utilizing the maximum capability of existing street systems. Construction costs and right-of-way acquisition problems may inhibit the construction of new freeways. It is imperative, therefore, that existing streets and highways be used to the maximum extent possible. Better methods of accommodating turns, cross-traffic flow, pedestrian movements, and parking needs must be found. Innovations with electronics in control and surveillance may be very beneficial to this problem.

Objective:

1. To develop ways and means of utilizing the maximum capability of existing streets and highways to achieve improved mobility of people and goods.

Priority: 2 (intermediate)

HRIS Subject Areas:

15	51
	53
	54
	55

Problem Area 2-3

Operation of Streets and Highways During Nighttime and Poor-Visibility Periods

A disproportionate share of accidents, in terms of exposure, occurs at night and during periods of fog and low visibility, as compared with a more favorable driving environment. Research is needed to reduce this toll and to provide safer operation on roadways during adverse weather at night and during poor-visibility periods. Principal areas to be studied include highway illumination, vehicle headlights, pavement reflectivity, and the effect of vehicle speed.

Objective:

1. To develop techniques, equipment, materials and lighting criteria that will permit safer operation on streets and highways at night and other poor-visibility periods.

Priority: 1 (low)

HRIS Subject Areas:

22	34	40	53	90
		41		

Problem Area 2-4

Development of Maintenance Techniques and Equipment Compatible with Operating Requirements on High-Speed Expressways

The speed and density of traffic on high-speed roadways, especially limited-access urban freeways, make standard maintenance operations extremely difficult and dangerous to the worker as well as the motorist. Closure of one or more lanes for repairs can be intolerable for proper operations. During the winter, snow and ice must be removed rapidly to prevent traffic congestion. Maintenance equipment and procedures, and barriers or protective devices, may be inadequate for full protection of workmen or they may prove to be safety hazards for the users of the facilities. As a result, some efficient compromises must be made to permit the maintenance necessary to provide a serviceable highway while minimizing the interruption or inconveniencing of traffic.

Objective:

1. To provide better and more rapid maintenance techniques, equipment, and material compatible with operational requirements on high-speed roadways.

Priority: 3 (high)

HRIS Subject Areas:

22	31	40
27		41

Problem Area 2-5

Surveillance and Control of Traffic Flow on Urban Street and Highway Systems

Modern surveillance techniques and control equipment are required to assist in improving traffic flow on urban roadways. These devices and methods can be used to survey, examine, predict, and remotely control the traffic flows on freeway ramps, lanes, arteries, and intersections. Aerial surveys, television monitors, sensing devices, and on-line computers must be added to the traditional uses of traffic counts, police control, signs, and signals in the densely traveled urban corridors.

Objectives:

1. To improve existing surveillance and control equipment, especially to be more sensitive and yet economical.
2. To devise new methods of surveillance and analysis for use on both expressways and high-capacity local urban streets.

Priority: 3 (high)

HRIS Subject Areas:

15	22	51	84
		52	
		53	
		54	

Problem Area 3-1

Aesthetic Considerations in the Design, Maintenance and Operation of Highways

Too frequently highway planners and designers have been forced by economic problems and administrative policies to neglect the beauty and aesthetics of highway construction. With financial allowances, the right-of-way could be landscaped, structure appearance could be enhanced, and highway locations could follow more eye-appealing routes. Proper aesthetic considerations need not increase the maintenance in many instances.

Objectives:

1. To provide guidelines as to the quantity and quality of aesthetic treatment that is desirable, and establish costs for such design enhancement.
2. To identify and delineate aesthetically desirable features that can be incorporated in highway designs.
3. To determine benefits to be derived from aesthetic treatment of highways, in monetary terms where possible.

Priority: 1 (low)

HRIS Subject Areas:

11	22	70	82
13	24		84
15			

Problem Area 3-2

Impact of Various Types of Design Features of Highways upon Environmental Values

Highways are one of the dominant features in the master plan of an area. The class of highway which a planner selects, its detailed location, and its design features greatly affect contiguous and adjacent land values and the nature and makeup of neighboring development. This cause-and-effect relationship is presently somewhat obscure, and too little is known about how to predict and assess this impact.

Objective:

1. To find ways and means of quantifying the impact of various types of highways or specific design features upon environmental values in the adjoining terrain.

Priority: 3 (high)

HRIS Subject Areas:

22	55	70	81
24			82
			83
			84

Problem Area 3-3

Accommodation of Multiple Use of Right-of-Way in Urban Ares

The high cost and scarcity of land areas require that multiple uses of rights-of-way be found that are compatible with the highway and the economy of the community. The portions of public land other than the travelway usually serve only as buffers between the road and its environs or as foundations for signing and other structures. Designers should find additional uses for this land, and for the attendant air rights, that are compatible with both the highway and urban settlement requirements. Planners should consider, as well, subterranean and aerial space for such uses as parking, utilities, and even buildings or extensions of structures.

Objectives:

1. To find practical ways of fully utilizing urban highway rights-of-way, both horizontally and vertically.
2. To study requirements and means of providing for safety, proper ventilation, noise abatement, structural protection, accessibility for maintenance, and other considerations.

Priority: 2 (intermediate)

HRIS Subject Areas:

11	24	70	82
13			83
15			84

APPENDIX C

CODE LISTS

CODE LISTS

PROJECT STATEMENT NUMBER

Each abbreviated project statement has been identified by a code number, such as 51-390.

The first two digits correspond to the HRIS subject area code (Table C-1). A particular statement may appear in more than one HRIS subject area, such as 51-390 or 24-390, etc.

The remaining digits designate a file code number (different for each project), which identifies the project and serves as a cross-reference to the original full statement from which the abbreviated statement was prepared.

PROJECT STATEMENT SOURCE CODES

The project statements were received from a variety of sources, including HRB committees, interviews, and other statements. Table C-2 identifies the source codes shown in Table D-3.

TABLE C-1

HRIS SUBJECT AREA CODE

HRIS CODE	SUBJECT AREA	HRIS CODE	SUBJECT AREA
11	Transportation Administration	51	Highway Safety
12	Personnel Management	52	Road User Characteristics
13	Land Acquisition	53	Traffic Control and Operations
14	Transportation Finance	54	Traffic Flow
15	Transportation Economics	55	Traffic Measurements
21	Photogrammetry	61	Exploration-Classification (Soils)
22	Highway Design	62	Foundations (Soils)
23	Highway Drainage	63	Mechanics (Earth Mass)
24	Roadside Development	64	Soil Science
25	Pavement Design		
26	Pavement Performance		
27	Bridge Design	70	Legal Studies
31	Bituminous Materials and Mixes	81	Urban Transportation Administration
32	Cement and Concrete	82	Urban Community Values
33	Construction	83	Urban Land Use
34	General Materials	84	Urban Transportation Systems
35	Mineral Aggregates		
40	Maintenance, General	90	Highway Research (General)
41	Construction and Maintenance Equipment		

TABLE C-2

SOURCE CODES

HRB DEPARTMENT OR OTHER SOURCE	CODE	HRB COMMITTEE NAME OR OTHER IDENTIFICATION
	(*a*) HRB COMMITTEES	
Design	D-A1	Photogrammetry and Aerial Surveys
	D-A2	Geometric Highway Design
	D-A3	Surface Drainage of Highways
	D-A4	Guardrail, Median Barriers and Sign, Signal Lighting Supports
	D-A5	Roadside Development
	D-B	Department of Design
	D-B1	Rigid Pavement Design
	D-B4	Surface Properties-Vehicle Interaction
	D-B5	Pavement Condition Evaluation
	D-C1	Bridge Design
	D-C2	Steel Superstructures
	D-C4	Substructures, Retaining Walls, and Foundations
	D-C5	Field Testing of Bridges
	D-C6	Bridge Dynamics
Economics, Finance, Administration	EFA-C4	Indirect Effects of Highway Improvements
Legal Studies	L-5	General
	LS-2	Urban-Metropolitan Transportation Law
	LS-4	State Highway Laws
Maintenance	M	General or Studded Tires
	M-2	Maintenance Costs
	M-3	Maintenance Personnel—Jointly with AASHO
	M-4	Salvaging Old Pavements by Resurfacing
	M-5	Snow and Ice Control
	M-7	Maintenance of Bituminous Pavements
	M-8	Maintenance of Controlled Access Highways
	M-10	Maintenance of Structures
	M-11	Maintenance of Portland Cement Concrete Pavements
	M-12	Maintenance Equipment

TABLE C-2 (*Continued*)

HRB DEPARTMENT OR OTHER SOURCE	CODE	HRB COMMITTEE NAME OR OTHER IDENTIFICATION
Materials and Construction	MC	General
	MC-B	General Concrete
	MC-C	General Construction
	MC-C3	Construction Practices, Earthwork
	MC-C4	Construction Practices, Structures
	MC-D	General Materials
	MC-D1	Mineral Aggregates
Soils, Geology, Foundations	SGF-A1	Compaction
	SGF-A2	Soil-Calcium Chloride Stabilization
	SGF-A3	Soil-Sodium Chloride Stabilization
	SGF-A4	Lime and Lime-Fly Ash Stabilization
	SGF-A5	Soil-Portland Cement Stabilization
	SGF-B1	Strength and Deformation Characteristics of Pavement Sections
	SGF-B2	Embankments and Earth Slopes
	SGF-B3	Foundations of Bridges and Other Structures
	SGF-B4	Buried Structures
	SGF-B5	Mechanics of Earth Masses in Layered Systems
	SGF-B6	Subsurface Drainage
	SGF-C1	Exploration and Classification of Earth Materials
	SGF-C2	Soil and Rock Properties
	SGF-C3	Physico-Chemical Phenomena in Soils
	SGF-C4	Frost Action
	SGF-C5	Environmental Factors Except Frost
	SGF-C6	Engineering Geology
Traffic and Operations	TO	General Traffic and Operations
	TO-1	Parking
	TO-3	Operational Effects of Geometrics
	TO-4	Highway Capacity
	TO-5	Traffic Control Devices
	TO-6	Highway Safety
	TO-7	Quality of Traffic Service
	TO-9	Theory of Traffic Flow
	TO-10	Freeway Operations
	TO-11	Road User Characteristics
	TO-12	Characteristics of Traffic Flow
	TO-13	Night Visibility
Urban Transportation Planning	UTP-2	Land-Use Evaluation
	UTP-3	Community Values
	UTP-4	Transportation System Evaluation
Special Committees	SC-8	Nuclear Principles and Applications
	(*b*) OTHER SOURCES	
HRB Framework Study Committee	FSC-1	Community Impact of Highway Improvement
	FSC-2	Transportation Economics
	FSC-3	Demographic Factors and Highway Use
	FSC-4	Economics of Design and Road User Impact
	FSC-5	Highway Investments and Highway Cost
	FSC-6	Highway Finance and Cost Allocation
	FSC-7	Administration and Management
	FSC-8	Right-of-way
Project staff	INT	Interviews conducted by project staff
BPR	MOST	Maintenance, Operations and Services to Traffic Research, program proposed by Deputy Director, Development; Office of Research and Development, Bureau of Public Roads

APPENDIX D

ILLUSTRATIVE RESEARCH PROGRAM

APPLICATION OF A STRUCTURING PROCESS

During the course of this study the 900 highway research project statements made available to the research agency staff were placed in a large stockpile of potential highway research projects. An abbreviated statement was prepared for each, and each was assigned one or more HRIS subject area codes.

Costs were estimated only for each of the selected project statements. These cost estimates, as described in Chapter Six, were made on the basis of professional man-months required to complete the project, with $3,000 assigned to each man-month of effort. In addition, each project was assigned an initiation cost of $25,000.

HRIS subject area codes were also assigned to the problem areas. As an example of the process, Problem Area 1-2, "Design and Construction Criteria for the Accommodation of Maintenance," was assigned the following 9 HRIS subjects:

HRIS CODE	SUBJECT
23	Highway drainage
27	Bridge design
40	General maintenance
41	Construction-maintenance equipment
51	Highway safety
53	Traffic control operations
54	Traffic flow
55	Traffic measurements
64	Soil science

Each of the other 12 current problem areas had a similar list of subjects and codes assigned to it.

A mechanical matching of the HRIS codes was accomplished and an evaluation of the proposed projects identified by the matching process was made by the study staff to determine the worthiness of the projects for the particular problem area. During this evaluation some project statements were modified, others were combined, and some were returned to the general listing as being inappropriate. At this point in the process, the selected list of appropriate research project statements was also examined for each problem area and analyzed for any obvious "gaps" in the list of proposed projects. Had there been any obvious gaps, a project or projects would have been prepared to close them. Finally, a priority (3-high, 2-intermediate, and 1-low) was assigned to each proposed project within a given problem area through the composite judgment of several staff members, based on the relative importance of the project to the particular problem area.

Weighted priorities were assigned to each project by multiplying the project priorities by the problem area priorities. When a project appeared in more than one problem area, the weighted priorities were added to obtain a composite priority for the project.

RESULTING RESEARCH PROGRAM

The results of this selection process are summarized in Table D-1, which shows a total of 253 projects identified among the 13 problem areas, requiring 6,182 professional man-months of effort. Duplication of projects in more than one problem area made a total of 326 projects overall. The required 6,182 man-months of effort created a total funding need of $24,871,000 for these projects. This total value is high when related to existing annual programs, and is about equal to the total annual Federal aid to States for highway research.

A summation of results of calculating the composite priorities is shown in Table D-2. The composite priorities range from a low of 1 for 22 projects to a high of 20 for a single project. It is interesting to note that of the $24-million program only 19 projects totaling $2,194,000 fall in the top 10 composite priority ratings. This emphasizes the broad, multiproject base on which most of the major problem solutions must be built.

Project Tabulation

Tables D-3, D-4, and D-5 provide detailed information on the research project proposals selected from the stockpile as responsive to the 13 problem areas, as follows:

Table D-3 gives selected project statements within each identified problem area, with the HRIS subject area code, the project-identifier code, and the estimated project cost. The source of the full statement can be decoded from the accompanying code lists.

The numbers in parentheses, where they occur, indicate the HRB Research Circular number in which the statement was published.

Table D-4 gives the priority assigned to each project within each problem area. This detailed table is summarized in Table D-1.

Table D-5 gives each selected project by calculated composite priority in descending order. The information in this detailed table is summarized in Table D-2. Note that projects which appear in more than one problem area are repeated, and are identified by "X".

TABLE D-1

SUMMARY OF RESEARCH NEEDS

PROBLEM AREA [a]	NUMBER OF PROJECTS [b] PRIORITY 1	PRIORITY 2	PRIORITY 3	TOTAL	EST. PROF. MAN-MONTHS	EST. FUNDING [c] ($1,000) PROJECT	INITIATION	TOTAL
1-1	8	13	5	26	612	1,836	650	2,486
1-2	3	8	6	17	430	1,290	425	1,715
1-3	8	16	3	27	605	1,815	675	2,490
1-4	6	6	3	15	365	1,095	375	1,470
1-5	9	14	4	27	716	2,148	675	2,823
2-1	3	6	5	14	407	1,221	350	1,571
2-2	9	23	5	37	897	2,691	925	3,616
2-3	10	13	6	29	779	2,337	725	3,062
2-4	7	10	5	22	606	1,818	550	2,368
2-5	8	23	9	40	939	2,817	1,000	3,817
3-1	2	15	10	27	656	1,968	675	2,643
3-2	5	16	6	27	649	1,947	675	2,622
3-3	6	7	5	18	443	1,329	450	1,779
All	84	170	72	326	8,104	$24,312	$8,150	$32,462
Duplication				—73	—1,922	—5,766	—1,825	—7,591
Net				253	6,182	$18,546	$6,325	$24,871

[a] See Chapter Five for explanation of problem areas.
[b] Priority 1, low; 2, intermediate; 3, high.
[c] Costs = (Man-months × $3,000) + (No. of projects × $25,000); see Table D-4 for detailed costs.

TABLE D-2

SUMMARY OF RESEARCH COSTS BY PROJECT PRIORITY LEVEL

OVERALL PRIORITY LEVEL [a]	NO. OF PROJECTS	ESTIMATED COST ($1,000) PER LEVEL	ACCUMULATED
20	1	133	133
19	2	176	309
18	1	109	418
15	5	626	1,044
13	6	762	1,806
12	2	212	2,018
11	2	176	2,194
10	12	1,203	3,397
9	20	1,895	5,292
8	6	573	5,865
7	4	388	6,253
6	66	6,441	12,694
5	5	470	13,164
4	18	1,635	14,799
3	40	4,078	18,877
2	41	3,758	22,635
1	22	2,236	24,871
All	253	24,871	—

[a] Derived for each project by multiplying the project priority by the problem area priority to obtain a "weighted" priority, then adding weighted priorities where the project occurred in more than one problem area.

TABLE D-3
RESEARCH PROJECT STATEMENTS BY PROBLEM AREA

PROBLEM AREA 1-1 PROJECT STATEMENTS

QUALITY CONTROL OF HIGHWAY CONSTRUCTION

CODE NO.	SOURCE	COST
23- 91	MC D (53)	$ 70

IMPROVED SPECIFICATIONS OF MINIMUM DEFORMED FABRIC STEEL REQUIREMENTS FOR ALL CLASSES AND DIAMETERS OF CONCRETE CULVERT PIPE.

25- 112	SGFB1 (37)	$ 79

INVESTIGATION, BY MEANS OF HIGH-PRESSURE TRIAXIAL TESTING, DEFORMATION PROPERTIES OF MACADAM BASES AND CORRELATION OF THESE CHARACTERISTICS WITH EQUIVALENT PLATE-LOAD OR DYNAMIC TEST CHARACTERISTICS.

25- 114	SGFB1 (37)	$ 79

LABORATORY TESTING AND EVALUATION PROCEDURES FOR PAVEMENT SURFACING AND SUBSURFACING ELEMENTS, RELATING TO THE FIELD LOADING ENVIRONMENT.

25- 115	SGFB1 (37)	$ 97

ESTABLISHMENT OF DETAILED CRITERIA AND TECHNIQUES FOR THE TRIAXIAL EVALUATION OF PAVING MATERIALS.

26- 69	MC C (52)	$ 97

DEVELOPMENT OF AN IMPROVED PROCEDURE FOR SPECIFYING AND CONTROLLING SMOOTHNESS OF PAVEMENT SURFACE DURING CONSTRUCTION.

26- 463	D 804 (61)	$133

DEVELOPMENT OF A NON-CONTACT, HIGH SPEED PROFILOMETER.

31- 253	MOST	$ 79

DEVELOPMENT OF AND INSTRUMENTS FOR FIELD MEASUREMENT OF KINEMATIC VISCOSITY OF ASPHALT IN CUT-BACK AND EMULSION FORM

32- 254	MOST (62)	$ 97

DEVELOPMENT OF CRITERIA FOR DEFINING UNSOUND CEMENT CONCRETE AND DEVELOPMENT OF A TEST METHOD FOR DETERMINING UNSOUNDNESS

33-1107	INT	$ 70

DEVELOP A FIELD TEST TO ASSURE THAT THE STRENGTH OF FIELD WELDS MEETS DESIGN STANDARDS.

34- 76	MC D (52)	$ 97

DETERMINATION OF A SAMPLING PROCEDURE FOR CRUSHED STONE WHICH WOULD GIVE RESULTS WITH KNOWN DEGREE OF CONFIDENCE.

34-1009	INT	$ 97

DEVELOP MATERIAL SPECIFICATIONS AND TESTING PROCEDURES THAT GIVE RECOGNITION TO STATISTICAL VARIATIONS WHICH WILL OCCUR IN LARGE-SCALE TESTING PROGRAMS.

40- 207	MOST (62)	$115

DEVELOPMENT OF GUIDELINES FOR SELECTING REGIONALLY THE BEST MATERIALS FOR THE CONSTRUCTION OF NON-SKID SURFACES, BY MEANS OF A STUDY OF MATERIALS AND METHODS USED IN THE PAST.

40- 267	M 02 (62)	$169

DEVELOPMENT OF STANDARDS FOR MEASURING THE QUALITY AND ADEQUACY OF THE MAINTENANCE PERFORMED ON VARIOUS HIGHWAY SYSTEMS AND UNDER VARIOUS JURISDICTIONS THE OBJECT IS TO ESTABLISH A LEVEL OF MAINTENANCE ECONOMICALLY JUSTIFIED ON A BENEFIT-COST RATIO.

CODE NO.	SOURCE	COST
41- 29	SC 8	$ 97

DEVELOPMENT OF PROTOTYPE EQUIPMENT TO MEASURE PAVEMENT THICKNESS BY RADIOACTIVE TECHNIQUES.

41- 30	SC 8	$ 97

DEVELOPMENT OF A RADIOACTIVE SYSTEM TO DETERMINE PAVEMENT STRENGTH.

41- 183	MOST	$ 97

DEVELOPMENT OF RAPID METHODS FOR QUALITY CONTROL OF MAINTENANCE MATERIALS.

41- 230	MOST (62)	$ 97

DEVELOPMENT OF DEVICE TO MEASURE PAVEMENT CONTOUR INCLUDING PROFILE AND TRANSVERSE SLOPE.

41- 255	MOST (62)	$145

USE OF NUCLEAR AND SONIC DEVICES FOR DETERMINATION OF THE POSITION AND CONDITION OF REINFORCING STEEL AND OF THE SOUNDNESS OF WOOD.

61- 33	SC 8	$ 97

DEVELOPMENT OF A LABORATORY DEVICE EMPLOYING THE USE OF A RADIOISOTOPE TO DETERMINE MOISTURE AND DENSITY OF COMPACTED SAMPLES.

61- 72	MC C3 (52)	$ 97

FIELD TESTING PROCEDURE FOR RAPID AND ACCURATE DETERMINATION OF CLASSIFICATION, OPTIMUM DENSITY, MAXIMUM MOISTURE, AND DEGREE OF COMPACTION FOR SOILS.

61- 153	SGFC1 (37)	$ 79

EVALUATION OF PRESENTLY AVAILABLE EQUIPMENT AND PROCEDURES FOR SAMPLING SAND AND GRAVEL DEPOSITS AND DEVELOPMENT, IF POSSIBLE, OF NEW EQUIPMENT AND TECHNIQUES.

62- 97	SGFA1 (37)	$ 61

EVALUATION OF PROPERTIES OF SOILS COMPACTED IN THE FIELD IN RELATION TO THE PROPERTIES OF SAMPLES COMPACTED BY STANDARD LABORATORY TESTS.

62- 99	SGFA1 (37)	$ 85

DEVELOPMENT OF CRITERIA NEEDED FOR TEST ROLLING SOILS OF DIFFERENT TYPES AND VARYING CONDITIONS TO INSURE CAPABILITY AND ESTABLISHMENT OF A CORRELATION BETWEEN THESE DATA AND SUBGRADE BEARING VALUES.

62- 100	SGFA1 (37)	$ 97

DETERMINATION OF THE MINIMUM COMPACTION FOR ALL HEIGHTS OF EMBANKMENT AND ALL SOIL TYPES TO ENSURE THAT HIGHWAY EMBANKMENTS WILL NOT CONSOLIDATE BY DETRIMENTAL AMOUNTS.

64- 107	SGFA3 (37)	$ 79

DEVELOPMENT OF LABORATORY TESTS TO INDICATE QUALITATIVE AND QUANTITATIVE IMPROVEMENT OF SOILS FROM THE STABILIZATION PROVIDED BY SODIUM CHLORIDE AND CALCIUM CHLORIDE.

64- 109	SGFA4 (37)	$ 79

DETERMINATION OF UNIFORM TEST PROCEDURES FOR QUALITY CONTROL AND DURABILITY OF LIME TREATED SOILS AND AGGREGATES.

Note· All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 1-2 PROJECT STATEMENTS

DESIGN AND CONSTRUCTION CRITERIA FOR THE ACCOMMODATION OF MAINTENANCE

CODE NO.	SOURCE	COST	STATEMENT
23- 440	D A02 (61)	$ 70	DETERMINATION OF FEASIBILITY OF SLOPING PAVEMENTS ON DIVIDED HIGHWAYS TO DRAIN TOWARD THE MEDIAN IN ORDER TO MINIMIZE MOISTURE CONCENTRATION UNDER THE OUTSIDE LANE.
27- 292	M 10 (62)	$ 97	DEFINITION OF CRITERIA AND TYPE OF APPURTENANCES TO BE USED FOR MAINTENANCE FACILITIES FOR LARGE, LONG-SPAN BRIDGES. INITIAL CONSTRUCTION SHOULD TAKE INTO ACCOUNT NEED FOR MAINTENANCE FACILITIES.
27- 431	D A02 (61)	$100	BALANCE OF BENEFITS AGAINST COSTS FOR SHOULDERS ON BRIDGE STRUCTURES AND CLASSIFICATION OF STRUCTURES ON WHICH FULL SHOULDERS ARE WARRANTED.
40- 300	M 2	$ 61	STUDY OF FEASIBILITY OF FLUSH-MOUNTING HIGHWAY DELINEATORS TO ELIMINATE THE MAINTENANCE PROBLEM PRESENTED BY CONVENTIONAL TYPE DELINEATORS.
40- 304	M 10 (62)	$ 79	ESTABLISHMENT OF GUIDELINES AND METHODS FOR UNDERDRAIN AND FILTER MATERIAL MAINTENANCE.
40- 387	TO 6 (45)	$115	PREVENTION OF THE SURFACE OF BRIDGES FROM ICING PRIOR TO APPROACH PAVEMENTS.
40- 561	FSC04	$115	DETERMINATION OF EFFECT UPON THE ROAD USER OF MAINTENANCE OPERATIONS.
40-1166	INT	$115	DEVELOP BETTER SNOW AND ICE REMOVAL TECHNIQUES AND DESIGN HIGHWAY CROSS SECTIONS TO MINIMIZE SNOW DRIFTING.
41- 279	M 05	$115	EVALUATION OF EXISTING BURIED-PIPE AND INFRARED ICE-MELTING SYSTEMS TO DETERMINE MINIMUM HEAT REQUIREMENTS AND WEAKNESSES IN THE DESIGN.
41- 451	D A 5	$ 97	ESTABLISH CRITERIA FOR EVALUATION OF FUNCTION, DESIGN, AND LOCATION OF HIGHWAY REST AREAS.
41-1006	INT	$169	EVALUATE HIGHWAY DESIGN FEATURES-SUCH AS IRREGULAR OR NARROW TURF AREAS, STEEP SLOPES, INACCESSIBLE AREAS, ETC. TO PERMIT MECHANIZATION OF MAINTENANCE ACTIVITIES SUCH AS MOWING, CLEANING, AND PAINTING. THE RESULTANT USE OF HAND LABOR IS COSTLY AND OFTEN DANGEROUS.
51- 388	TO 10	$ 61	DETERMINATION OF NEED FOR CROSSOVERS ON THE INTERSTATE SYSTEM TO PREVENT THE INTERSTATE FROM BECOMING MORE HAZARDOUS.
51-1162	INT	$ 97	DEVELOP ADDITIVES FOR ASPHALT AND CONCRETE PAVEMENTS TO PREVENT THE FORMATION OF ICE AND TO PREVENT SLIPPERINESS IN WET WEATHER.
53- 409	TO 10 (39)	$115	DETERMINATION OF DESIGN CRITERIA FOR SHOULDERS ON THE INTERSTATE SYSTEM WHICH WILL HAVE MINIMAL COST FOR MAINTENANCE AND CAPITAL IMPROVEMENT.
54-2210	TO 3 (39)	$115	DETERMINE THE DIFFERENCES IN CHARACTERISTICS OF TRAFFIC FLOW BETWEEN SPACIOUS AND CONSTRICTED INTERCHANGES.
55-2205	TO 2 (31)	$ 97	COLLECTION OF DATA ON WEEKEND AND RECREATIONAL TRAVEL.
64-1109	INT	$ 97	APPROACH SLABS TO BRIDGE. A NEED EXISTS TO IMPROVE THE DESIGN AND MAINTENANCE TECHNIQUE OF APPROACH SLABS TO BRIDGES.

Note: All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 1-3 PROJECT STATEMENTS

STANDARDS FOR RELATING LEVELS OF SERVICE ON FREEWAYS TO ECONOMIC AND LAND-USE COSIDERATIONS

CODE NO.	SOURCE	COST
15- 431	D A02 (61)	$100
BALANCE OF BENEFITS AGAINST COSTS FOR SHOULDERS ON BRIDGE STRUCTURES AND CLASSIFICATION OF STRUCTURES ON WHICH FULL SHOULDERS ARE WARRANTED.		
15- 583	FSC06	$ 97
DETERMINATION OF THE PRICING OF HIGHWAY SERVICES, PARTICULARLY THE ALLOCATION OF COSTS FOR ADDED CAPACITY FOR URBAN COMMUTER TRAFFIC.		
15- 649	FSC06	$ 97
STUDY OF THE ALLOCATION OF EXPRESSWAY COSTS INCLUDING BOTH USER AND NON-USER BENEFITS.		
15-2097	INT	$ 97
DEVELOP STANDARDS FOR THE JUSTIFICATION FOR VARIOUS LEVELS OF SERVICE IN BOTH URBAN AND RURAL AREAS.		
22- 315	TC 03 (39)	$ 79
DETERMINATION OF BEST DESIGN FOR MEDIANS ON URBAN EXPRESSWAYS WHERE RIGHT OF WAY IS COSTLY OR OTHERWISE LIMITED.		
22- 359	TC 09 (24)	$ 97
STUDY OF WHEN THE NET EFFECT OF TRAFFIC COMPOSITION AND LOADING IN A GIVEN ENVIRONMENTAL SITUATION REQUIRES ADDITIONAL LANES, OR WIDER LANES, OR WIDER SHOULDERS, ETC.		
22- 408	TC 03 (39)	$ 97
DETERMINATION OF THE STRUCTURAL REQUIREMENTS OF SHOULDERS FOR THE DESIGN TRAFFIC AND ESTABLISHMENT OF THE RELATIONSHIP OF THE FUNCTION OF THE SHOULDER STRUCTURE TO THE THROUGH PAVEMENT STRUCTURE.		
22- 410	TC 10 (39)	$ 61
ESTABLISHMENT OF THE NEED, THE CRITERIA, AND DESIRABLE WIDTHS FOR LEFT SHOULDERS ON MULTILANE DIVIDED HIGHWAYS, PARTICULARLY ON THE THREE LANE DIRECTIONAL HIGHWAYS.		
22- 422	D A02 (61)	$ 85
DETERMINATION OF THE CONDITION UNDER WHICH A COLLECTOR-DISTRIBUTOR ROAD IS THE MOST ADVANTAGEOUS DESIGN.		
22- 430	D A02 (61)	$115
EVALUATION OF THE PERFORMANCE AND SUITABILITY OF VARIOUS NARROW MEDIAN DESIGNS TO DETERMINE ACCEPTABLE CRITERIA FOR ACHIEVING SAFETY AND ECONOMY.		
22- 434	D A02 (61)	$115
DETERMINATION DESIRABLE GEOMETRIC DESIGN FOR FREEWAY RAMP TERMINALS.		
22-2042	INT	$ 97
DEVELOP DESIGN STANDARDS FOR JUNIOR EXPRESSWAYS TO LESSEN RIGHT-OF-WAY AND CONSTRUCTION COST REQUIREMENTS, AS WELL AS DETRIMENTAL IMPACT ON LAND USES AND OTHER CONSIDERATIONS.		
52- 346	TU 07 (25)	$ 79
DEVELOPMENT OF A METHOD FOR RATING EXISTING OR PROPOSED TRAFFIC SERVICE FACILITIES FOR THE LEVEL OF SERVICE PROVIDED.		
53- 425	D A02 (61)	$ 79
DETERMINATION OF BEST TYPE OF ACCELERATION AND DECELERATION LANES APPLICABLE TO AT-GRADE INTERSECTIONS AND INTERCHANGE RAMP ENTRANCE AND EXIT TERMINALS.		
53- 428	D A02 (61)	$115
DETERMINATION OF BEST GEOMETRIC DESIGN FOR REDUCING THE NUMBER OF THROUGH LANES ON FREEWAYS, INCLUDING THE LOCATION FOR INTERCHANGE RAMP TERMINALS, THE GEOMETRIC DESIGN OF TRANSITION AREAS AND SIGNING AND DELINEATION AT THE TRANSITION.		
53- 432	D A02 (61)	$ 85
ESTABLISHMENT OF SPECIFIC DESIGN CRITERIA FOR EACH HIGHWAY INTERCHANGE TYPE AND PREPARATION OF A COMPREHENSIVE SUMMARY OF SELECTED EXISTING INTERCHANGES RELATING VEHICULAR OPERATION TO DESIGN VARIABLES.		
53- 435	D A02 (61)	$ 97
DETERMINATION OF THE BEST TYPE OF INTERSECTION AT A CROSSROAD RAMP TERMINAL FOR DIFFERENT CONDITIONS AND THE DEVELOPMENT OF BASIC DESIGNS FOR CROSSROAD RAMP TERMINALS.		
53- 436	D A02 (61)	$ 97
DETERMINATION OF MINIMUM DISTANCES BETWEEN SUCCESSIVE RAMP TERMINALS AND THE MINIMUM DISTANCES BETWEEN AN ENTERING RAMP AND AN EXITING RAMP UNDER VARYING CONDITIONS.		
53- 439	D A02 (61)	$ 79
DETERMINATION OF MINIMUM DESTANCES FROM RAMP TERMINI TO THE END OF ACCESS CONTROL FOR VARIOUS CROSSROAD RAMP TERMINAL DESIGNS AND OF MINIMUM DISTANCE FROM RAMP TERMINI TO CROSSOVERS ON DIVIDED CROSSROADS.		
53-2209	TO 3 (39)	$ 97
EVALUATE EFFECT OF SIGHT DISTANCE ON TRAFFIC OPERATIONS IN THE VICINITY OF FREEWAY RAMP TERMINALS.		
54-2205	TC 2 (31)	$ 97
COLLECTION OF DATA ON WEEKEND AND RECREATIONAL TRAVEL.		
54-2210	TO 3 (39)	$115
DETERMINE THE DIFFERENCES IN CHARACTERISTICS OF TRAFFIC FLOW BETWEEN SPACIOUS AND CONSTRICTED INTERCHANGES.		
55- 353	TO 7	$115
FORMULATION OF MATHEMATICAL MODELS ON VEHICULAR SPEEDS IN URBAN AREAS UNDER VARIOUS TRAFFIC AND ENVIRONMENTAL CONDITIONS.		
55- 376	TO 10 (45)	$ 43
DEVELOPMENT OF A LIST OF TYPES OF VEHICLES, ANIMALS, AND EQUIPMENT WHICH SHOULD BE PROHIBITED FROM THE INTERSTATE SYSTEM.		
55- 570	FSC04	$115
DETERMINATION OF THE BENEFITS TO USERS OF IMPROVED HIGHWAYS AND THE BENEFITS TO THE USERS OF THE OLDER HIGHWAYS AS A RESULT OF LOWERED VOLUMES.		
55-2201	TO 2 (31)	$ 79
STANDARDIZATION OF DATA COLLECTION AREA UNITS.		
83- 713	L 05	$ 61
ANALYSIS OF ADMINISTRATION OF ACCESS CONTROLS TO INDICATE HOW LEGAL CONTROLS CAN BE MADE TO REFLECT CHANGING LAND USE AND TRAFFIC NEEDS.		

Note: All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 1-4 PROJECT STATEMENTS

DETERMINATION OF SIZES, WEIGHTS, AND PERFORMANCE REQUIREMENTS FOR HIGHWAY VEHICLES

CODE NO.	SOURCE	COST
22-1004	INT	$115

DETERMINE FIRM LIMITS ON VEHICLE SIZE AND WEIGHT TO PERMIT LONG-RANGE DESIGN PLANNING.

CODE NO.	SOURCE	COST
31- 55	MC A (50)	$ 97

DETERMINATION OF EFFECTS ON SKID RESISTANCE OF AGGREGATE TYPE, SIZE AND GRADING, SURFACE TEXTURE, AND THE SPEED OF THE VEHICLE.

CODE NO.	SOURCE	COST
40-1011	INT	$100

EXAMINE IMPROVED UNIFORMITY OF HIGHWAY LAWS REGULATING THE DESIGN, CONSTRUCTION, MAINTENANCE, AND OPERATION OF HIGHWAYS.

CODE NO.	SOURCE	COST
51- 19	UTP14	$ 79

CORRELATION BETWEEN HANDLING CHARACTERISTICS OF VARIOUS CLASSES OF VEHICLES AND THEIR SAFETY RECORDS.

CODE NO.	SOURCE	COST
51-1153	INT	$100

DETERMINE AND DISSEMINATE TO THE VEHICLE DRIVER OPTIMUM SPEEDS FOR A GIVEN SET OF TRAFFIC CONDITIONS BY USING COMPUTERS AND OTHER ELECTRONIC DEVICES.

CODE NO.	SOURCE	COST
52-2043	INT	$ 79

EVALUATE EXAMINATION AND LICENSING OF DRIVERS OF CERTAIN AGE AND PHYSICAL CAPABILITIES AND RESTRICT CERTAIN VEHICLES IN POOR CONDITION FROM HIGH SPEED FACILITIES.

CODE NO.	SOURCE	COST
55- 18	UTP14	$100

ESTABLISHMENT OF GUIDELINES FOR MORE CONSISTENT SPEED LIMITS, BASED ON VEHICLE, DRIVER, AND HIGHWAY CHARACTERISTICS.

CODE NO.	SOURCE	COST
55- 332	TO 6 (45)	$ 97

DETERMINATION BY BRAND NAMES, OF THE ROLE OF DESIGN, SIZE, AND WEIGHT THAT VEHICLES PLAY IN TRAFFIC SAFETY.

CODE NO.	SOURCE	COST
55- 351	TO 04	$ 97

DEVELOPMENT OF REFINED KNOWLEDGE ON THE INFLUENCE OF TRUCKS ON THE TRAFFIC-CARRYING CAPACITIES OF INTERCITY RURAL HIGHWAYS.

CODE NO.	SOURCE	COST
55- 353	TO 7	$115

FORMULATION OF MATHEMATICAL MODELS ON VEHICULAR SPEEDS IN URBAN AREAS UNDER VARIOUS TRAFFIC AND ENVIRONMENTAL CONDITIONS.

CODE NO.	SOURCE	COST
55- 368	TO 12	$115

STUDY OF VEHICLE STOPPING CHARACTERISTICS AT NIGHT IN ORDER TO ESTABLISH A DESIGN STOPPING SIGHT DISTANCE ANALYSIS OF OPERATIONAL FACTORS SUCH AS OBJECT, HEADLIGHT BEAM, ROADWAY GEOMETRICS AND SAFETY FACTORS, IN ORDER TO PROPOSE A MAXIMUM NIGHT SPEED LIMIT.

CODE NO.	SOURCE	COST
55- 375	TO 12 (45)	$ 85

DEVELOPMENT OF CRITERIA FOR SPEED LIMITS ON RURAL HIGHWAYS THAT WOULD BE ESTABLISHED BY PARTICULAR ROAD DESIGN RATHER THAN BY BLANKET STATE-WIDE FIAT.

CODE NO.	SOURCE	COST
55- 376	TO 10 (45)	$ 43

DEVELOPMENT OF A LIST OF TYPES OF VEHICLES, ANIMALS, AND EQUIPMENT WHICH SHOULD BE PROHIBITED FROM THE INTERSTATE SYSTEM.

CODE NO.	SOURCE	COST
55- 635	FSC04	$133

ESTABLISHMENT OF MAXIMUM, MINIMUM, AND OPTIMUM POTENTIAL ACCELERATION CAPABILITIES OF PASSENGER CARS, SINGLE-UNIT TRUCKS, AND TRAILER COMBINATIONS.

CODE NO.	SOURCE	COST
55-1030	INT	$115

RELATE DEMAND FOR HIGHER SPEEDS AND INCREASING OF SPEED LIMITS AND NEED FOR MORE KNOWLEDGE ON SPEED CONSIDERATIONS IN VEHICLE-DRIVER-HIGHWAY SYSTEM.

Note: All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 1-5 PROJECT STATEMENTS

CRITERIA FOR THE INTEGRATION OF HIGHWAYS WITH OTHER MODES IN THE TOTAL TRANSPORTATION SYSTEM

CODE NO.	SOURCE	COST
11-1051	INT	$ 85
DETERMINE ACCEPTABLE LEVELS OF COMFORT, SAFETY, CONVENIENCE IN PLANNING VARIOUS MIXES OF TRANSPORTATION MODES.		
22-2004	INT	$133
DEVELOP GUIDELINES ON SUCH MATTERS AS WHEN TO DEPRESS OR ELEVATE HOW TO RELATE FREEWAYS TO PARKING FACILITIES HOW TO COORDINATE WITH PUBLIC TRANSPORTATION FACILITIES IN HIGHWAYS OR OTHERWISE AIR RIGHTS VEHICULAR-PEDESTRIAN SEPARATIONS ROAD PLANS RELATED TO URBAN RENEWAL PROGRAM.		
22-2210	TO 3 (39)	$115
DETERMINE THE DIFFERENCES IN CHARACTERISTICS OF TRAFFIC FLOW BETWEEN SPACIOUS AND CONSTRICTED INTERCHANGES.		
55- 326	TO 01 (26)	$ 79
DEVELOPMENT OF CRITERIA FOR SUCCESSFUL CHANGE OF MODE PARKING IN ALL SIZED CITIES.		
55- 344	TO 07 (25)	$175
QUANTIFICATION OF THE PARAMETERS THAT DEFINE THE QUALITY OF TRAFFIC SERVICE ON BOTH RURAL & METROPOLITAN TRANSPORTATION SYSTEMS AND RELATION OF THESE PARAMETERS TO EACH OTHER.		
55- 401	TO 04	$115
DETERMINATION AND EVALUATION OF ALL MEANS OF MAKING TRANSIT SERVICES SPEEDY AND ATTRACTIVE IN THE MORE CONGESTED URBAN AREAS.		
55-2201	TO 2 (31)	$ 79
STANDARDIZATION OF DATA COLLECTION AREA UNITS.		
55-2202	TO 2 (31)	$133
DETERMINE THE DIFFERENCES IN TRIP PRODUCTION PER HOUSEHOLD OBTAINED THROUGH THE USE OF PERSONAL VERSUS TELEPHONE INTERVIEWING METHODS.		
55-2206	TO 2 (31)	$115
DETERMINE THE SENSITIVITY OF ASSIGNED TRAFFIC TO CHANGES IN TRIP DISTRIBUTION AS CALCULATED BY MATHEMATICAL MODELS.		
81-2034	INT	$115
EVALUATE FACTORS OF URBAN LIFE TO HELP PLAN AND PROVIDE IMPROVED URBAN ENVIRONMENTS AND TRANSPORTATION IN THE FUTURE. MANY SOCIO-ECONOMIC DISCIPLINES ARE INVOLVED, NOT JUST ENGINEERS AND PLANNERS.		
81-2200	TO 2 (31)	$ 79
DETERMINATION OF ADEQUATE HOME INTERVIEW SAMPLE SIZES FOR TRANSPORTATION SURVEYS.		
84- 6	UTP03	$ 97
DEVELOPMENT OF A STANDARD METHOD FOR MEASURING THE SOCIO ECONOMIC CHARACTERISTICS AND ATTITUDES OF USERS OF MASS TRANSIT, INCLUDING A REVIEW OF PAST PRACTICES IN TRANSIT PASSENGERS STUDIES.		
84- 20	UTP04	$115
EVALUATION OF FEASIBILITY OF ALL BUS TRANSIT OPERATION IN INTERMEDIATE SIZE CITIES WHICH WOULD UTILIZE RESERVED RIGHTS OF WAY AND LIMITED STOPS. THE OBJECT WOULD ALSO INCLUDE INVESTIGATION OF ONE OR MORE OF THE MOST PROMISING TRANSPORTATION SYSTEMS IN INTERMEDIATE SIZE CITIES.		
84- 21	UTP04	$ 97
DETERMINATION OF DEMAND FOR TRANSPORTATION TO AND FROM MAJOR AIRPORTS AND THE FEASIBILITY OF A VARIETY OF MEANS MEETING THIS DEMAND.		
84- 22	UTP04	$ 97
USE OF THE COST AND BENEFIT ESTIMATES OF URBAN TRANSPORTATION SYSTEM STUDIES TO EVALUATE PROPOSED SYSTEMS. SUGGESTED OBJECTIVES WOULD BE PREPARATION OF LISTS OF DATA FOR THIS EVALUATION PROCESS AND THEN DEVELOPMENT OF METHODS FOR EVALUATING PROPOSED ALTERNATIVE SYSTEMS.		
84- 24	UTP04	$115
QUANTITATIVE DESCRIPTION OF THE OPERATION OF URBAN PASSENGER TRANSFER POINTS FOR ALL COMBINATIONS OF MODES AND DEVELOPMENT OF MODELS FOR SIMULATING AND EVALUATING DIFFERENT DESIGNS UNDER VARIOUS LOADINGS.		
84- 26	UTP04	$ 97
DETERMINATION OF THE FORM OF MASS TRANSIT REQUIRED IN METROPOLITAN AREAS AND DETERMINATION OF WHICH VALUES SHOULD APPLY IN SEARCH OF NEW OR MODIFIED MASS TRANSIT SYSTEMS.		
84- 545	FSC02	$ 97
DETERMINATION OF MINIMUM TRANSPORTATION FACILITIES NEEDED FOR REPRESENTATIVE TYPE OF URBAN COMMUNITIES.		
84- 547	FSC02	$133
DETERMINATION OF THE DEMAND FOR MASS TRANSPORTATION FOR COMMUTING, BY MEANS OF EXPERIMENTATION THAT MAY REQUIRE SUBSIDIZING MASS TRANSIT COMPANIES.		
84- 548	FSC02	$ 61
DEVELOP GUIDELINES FOR A HIGHWAY CONSTRUCTION PROGRAM WHICH WILL KEEP ABREAST OF CURRENT NEEDS AND A STUDY OF OVERALL FUTURE TRANSPORTATION REQUIREMENTS.		
84- 558	FSC03	$ 85
EXAMINATION OF THE TRAVEL PATTERNS AND OTHER FACTORS THAT MIGHT BE AFFECTED BY THE ABILITY OF THE CONSUMERS TO BUY THE TYPE OF TRANSPORTATION MOST DESIRABLE.		
84- 600	FSC07	$ 85
DEPARTMENT OF ECONOMICS, FINANCE,AND ADMINISTRATION STUDY OF THE EFFECT OF METROPOLITAN PLANNING AGENCIES IN DEVELOPING A METROPOLITAN TRANSPORTATION SYSTEM.		
84- 619	FSC01	$115
COLLECTION OF COMPARABLE COST DATA FOR ALTERNATIVE MODES OF URBAN PASSENGER TRANSPORTATION, INCLUDING SOCIAL COSTS, PORTAL-TO-PORTAL COSTS, SEAT-MILE COSTS, PARKING COSTS, SUBSIDIZED COSTS, JOURNEY-TO-WORK COSTS.		
84-2046	INT	$115
EVALUATE POSSIBLE CHANGES IN TRAINS, BUSES, AND TAXIS WITH PARTICULAR EMPHASIS ON THE INTERACTIONS BETWEEN COMBINATIONS OF THESE REVISED SYSTEMS AND CONSUMER NEEDS FOR URBAN TRANSPORT, ESPECIALLY IN LOW INCOME AREAS OF URBAN COMPLEXES		
84-2205	TO 2 (31)	$ 97
COLLECTION OF DATA ON WEEKEND AND RECREATIONAL TRAVEL.		
90-1113	INT	$ 97
EVALUATE INTERFACE PROBLEMS BETWEEN TRANSPORTATION SYSTEMS, TO HELP SPEED AND SIMPLIFY THE MOVEMENT BETWEEN SYSTEMS.		
90-1150	INT	$ 97
DEVELOP SCIENTIFIC PARAMETERS FOR EVALUATING DIFFERENT MODES OF URBAN TRANSPORTATION.		

Note: All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 2-1 PROJECT STATEMENTS

ACCOMMODATION OR REDUCTION OF OBSTRUCTIVE HIGHWAY APPURTENANCES

CODE NO.	SOURCE	COST	STATEMENT
22- 430	D A02 (61)	$115	EVALUATION OF THE PERFORMANCE AND SUITABILITY OF VARIOUS NARROW MEDIAN DESIGNS TO DETERMINE ACCEPTABLE CRITERIA FOR ACHIEVING SAFETY AND ECONOMY.
22- 447	D A04	$115	DETERMINATION OF THE OPTIMUM HEIGHT FOR GUARDRAILS.
22- 449	D A04 (61)	$130	DESIGN OF GUARDRAIL END THAT WILL PRESENT A MINIMUM HAZARD TO VEHICLE STRIKING IT.
22- 732	TO 01	$133	DETERMINATION OF TRAFFIC SAFETY ON FREEWAYS RELATED TO LOCATION OF LIGHTING AND SIGN STRUCTURES.
22-1019	INT	$145	EVALUATE CAUSES OF ACCIDENTS IN RELATIONSHIP TO THE DESIGN OF BETTER HIGHWAYS AND APPURTENANCES.
24- 390	TO 06 (46)	$130	STUDY OF THE LIKELIHOOD OF ACCIDENTS IN TERMS OF THE PROXIMITY OF FIXED OBJECT IN ORDER TO DESIGN SAFER STRUCTURES THAT MUST BE KEPT CLOSER TO THE TRAVEL WAYS AND TO ESTABLISH SAFE OFFSETS.
24- 411	TO 03 (39)	$ 97	DEVELOPMENT OF A STANDARD FOR PROTECTION OF PHYSICAL ELEMENTS ADJACENT TO THE SHOULDER AREA.
27- 17	UTP14	$ 79	UPDATING OF A A S H O BRIDGE RAIL SPECIFICATIONS THROUGH APPLICATION OF DEVELOPMENTS IN STRUCTURAL DYNAMICS AND ANALYTICAL METHODS OF RAIL PERFORMANCE PREDICTION.
53- 379	TO 06 (45)	$115	DETERMINATION OF HOW TO EFFECTIVELY DELINEATE OR ILLUMINATE OBSTRUCTIONS LOCATED WITHIN A ROADWAY IN ORDER THAT A NIGHT DRIVER MIGHT READILY COMPREHEND THE OBJECT.
53- 380	TO 06 (45)	$ 70	DETERMINATION OF THE BEST LOCATION FOR TRAFFIC SIGNAL FACES WITH MAXIMUM SIGNAL FACE OBSERVANCE.
53- 382	TO 05 (45)	$ 85	IMPROVEMENT OF CURRENT SIGNAL DESIGN AND INSTALLATION PRACTICES THROUGH IMPLEMENTATION OF DEMONSTRATED HUMAN FACTORS PRINCIPLES.
53-2041	INT	$145	DETERMINE PROPER PLACEMENT AND DESIGN OF SUPPORTS FOR OVER THE ROAD STRUCTURES TO DECREASE COLLISIONS AND REDUCE SEVERITY OF ACCIDENTS.
53-2045	INT	$115	DEVELOP GUIDELINES RELATING TO THE EXPENSE, DESIGN STANDARDS, AND PLACEMENT OF MAJOR SIGN STRUCTURES.
53-2209	TO 3 (39)	$ 97	EVALUATE EFFECT OF SIGHT DISTANCE ON TRAFFIC OPERATIONS IN THE VICINITY OF FREEWAY RAMP TERMINALS.

Note: All costs in thousands of dollars.

PROBLEM AREA 2-2 PROJECT STATEMENTS

UTILIZATION OF EXISTING STREETS AND HIGHWAYS TO THEIR MAXIMUM CAPABILITY

CODE NO.	SOURCE	COST	DESCRIPTION
15- 577	FSC05	$ 97	STUDY OF THE FULL COSTS OF URBAN STREET SYSTEMS.
15- 578	FSC05	$ 97	IMPROVEMENT OF TECHNIQUES FOR VALUATION OF URBAN STREETS SYSTEMS AND STUDY OF INVESTMENTS IN TYPICAL URBAN AREAS.
15- 579	FSC05	$115	DEVELOPMENT OF A SUFFICIENCY RATING SYSTEM OR INDEX OF ADEQUACY FOR URBAN STREETS.
15-1123	INT	$ 97	DEVELOP A METHOD FOR DETERMINING THE OPTIMUM NUMBER OF LANES ON A HIGHWAY VERSUS THE CONSTRUCTION OF A NEW HIGHWAY.
51- 386	TO 5	$133	ESTABLISHMENT OF RELATIONSHIP BETWEEN CAPACITY AND ACCIDENTS, USING PAVEMENT WIDTH AVAILABLE TO ENTERING TRAFFIC AND ACT VOLUME TO REPRESENT THE CAPACITY FACTOR. THE OBJECT IS THE EVENTUAL PREDICTION OF THE NUMBER OF ACCIDENTS LIKELY TO OCCUR AT LOCATIONS UNDER SIMILAR CONDITIONS.
51-1140	INT	$ 79	DETERMINE GUIDELINES FOR THE OPTIMUM MAXIMUM NUMBER OF LANES IN ONE DIRECTION ON HIGHWAYS FOR SAFETY AND ECONOMY'S SAKE.
53- 308	TO 01 (26)	$ 97	STUDY OF EASILY MEASURABLE DEMAND FACTORS, WHICH CAN BE APPLIED TO THE DETERMINATION OF PARKING AND TRAFFIC NEEDS FOR ARTERIAL STREETS AND DETERMINATION OF THE EFFECTS OF ZONING AND DENSITY CONTROLS ON PARKING DEMANDS.
53- 312	TO 07 (25)	$ 61	STUDY OF THE ACTUAL INSTALLATIONS OF TWO TYPES OF INTERSECTIONS, LONG CORNER CURB RADII PROVIDING A FREE RIGHT TURN THROUGH A CHANNELIZED SLOT AND THE STANDARD SHORT CORNER CURB RADII (25' TO 35') TO DETERMINE WHICH IS MORE ADVANTAGEOUS IN EASE OF TRAFFIC AND PEDESTRIAN FLOW.
53- 320	TO 03 (45)	$ 79	DEVELOPMENT OF A DESIGN FOR MEDIAN FOR SURFACE HIGHWAYS IN URBAN AREAS, PERMITTING GOOD ACCESS TO ABUTTING PROPERTY AND ACHIEVING HIGH CAPACITY FOR THROUGH MOVEMENTS AND MAXIMUM SAFETY.
53- 341	TO 05	$ 43	DETERMINATION OF THE LEVEL OF DISCOMFORT FOR DRIVER AT UNSIGNALIZED INTERSECTION.
53- 348	TO 04	$ 97	DETECTION OF REASONS FOR UNBALANCED USE OF URBAN ARTERIAL LANES BY DRIVERS AND DEVELOPMENT OF SUGGESTED PROCEDURES FOR MORE BALANCED USE.
53- 352	TO 12	$ 85	DETERMINATION OF FACTORS WHICH INFLUENCE A MOTORIST'S SELECTION OF HIS DESIRED TRAVEL LANE.
53- 360	TO 04	$ 79	DETERMINATION OF WHETHER THE BANNING OF LEFT TURNS AT INTERSECTIONS ON TWO-WAY STREETS IS TRULY PRACTICAL AND IF NOT, ESTABLISHMENT OF THE FEASIBILITY OF INSTALLATION OF MULTIPHASE SIGNALIZATION TO ACCOMMODATE THE TURNS.
53- 362	TO 04	$ 61	DETERMINATION OF FEASIBILITY OF COORDINATING ESSENTIAL MIDBLOCK TRAFFIC ENTRANCES WITH THE OVERALL ARTERIAL SIGNAL PROGRESSION.
53- 363	TO 04	$115	COMPARISON OF THE EFFICIENCY, AS A GROUP, OF SEVERAL STREETS MAKING UP A TRAFFIC CORRIDOR, WHEN OPERATING ONE-WAY AS COMPARED TO TWO-WAY.
53- 364	TO 04	$ 79	DEVELOPMENT OF PROCEDURES FOR DESCRIBING THE LEVEL OF SERVICE PROVIDED BY TWO-WAY STOP-CONTROLLED INTERSECTIONS UNDER ANY SPECIFIED VOLUME CONDITIONS.
53- 365	TO 10	$169	DEVELOPMENT OF DESIGN CRITERIA FOR TRAFFIC CONTROL SYSTEMS TO CONTROL THE DISTRIBUTOR SYSTEM AS A FUNCTION OF THE FREEWAY DEMAND.
53- 367	TO 10	$145	DETERMINATION OF HOW TO DISTRIBUTE TRAFFIC OVER FREEWAYS AND ARTERIAL STREETS TO BEST ACCOMMODATE PEAK-HOUR MOVEMENTS OF TRAFFIC.
53- 369	TO 05	$ 97	COLLECTION OF DATA CONCERNING THE PRESENT USE OF TRAFFIC SIGNALS IN UNUSUAL OR UNIQUE APPLICATIONS IN CONTROLLING VEHICULAR AND PEDESTRIAN TRAFFIC.
53- 370	TO 05	$ 70	REVIEW OF THE GENERAL PATTERN OF LONGITUDINAL MARKINGS INCLUDING DISTINGUISHING CENTER LINES FOR TWO-WAY ROADWAYS, REVERSIBLE LANE MARKING, CONTINUOUS LEFT-TURN LANES, ETC.
53- 424	D A03 (61)	$ 97	INCREASE OF KNOWLEDGE REGARDING THE DESIGN AND OPERATION OF 2-LANE TURNING ROADWAYS, INCLUDING THE DETERMINATION OF GEOMETRIC CRITERIA AND THE REEVALUATION OF EXISTING DESIGN STANDARDS FOR 2-LANE LEFT TURNS AT GRADE.
53-2062	INT	$133	DEVELOP WAYS AND MEANS OF DIVERTING THAT PORTION OF PEAK TRAFFIC WHICH WOULD CONGEST THE FREEWAYS BUT ALLOW EXPRESS BUSES ENTRY, AND DEVISE WAYS TO IMPROVE PEAK-HOUR FLOWS ON PARALLEL SURFACE FACILITIES. METHODS OF INFORMING MOTORISTS OF ALTERNATE ROUTES TO THEIR DESTINATIONS.
53-2211	TO 3 (39)	$ 97	DETERMINE CONFIGURATION OF INTERSECTION CHANNELIZATION WHICH PRODUCES OPTIMUM OPERATION AS RELATED TO MINIMUM USE OF LAND.
53-2212	TO 3 (39)	$115	DETERMINE OPERATION EFFECT OF SIGN PLACEMENT ON THE TRAFFIC STREAM.
54- 349	TO 04	$133	DEVELOPMENT OF INDICES TO MEASURE THE OVERALL LEVEL OF SERVICE PROVIDED ON SUBSTANTIAL LENGTHS OF URBAN ARTERIAL STREETS.
54- 361	TO 04	$ 97	DETERMINATION OF THE EFFECTIVENESS OF CONTINUOUS RESERVED LEFT-TURN LANE.
54- 425	D A02 (61)	$ 79	DETERMINATION OF BEST TYPE OF ACCELERATION AND DECELERATION LANES APPLICABLE TO AT-GRADE INTERSECTIONS AND INTERCHANGE RAMP ENTRANCE AND EXIT TERMINALS.
54- 433	D A02 (61)	$ 97	DEVELOPMENT OF A STANDARD EVALUATION PROCEDURE TO DETERMINE THE MOST SATISFACTORY STREET CROSS SECTION FOR ANY GIVEN SET OF CONDITIONS.
54-2073	INT	$115	DEVELOP A THEORETICAL BASIS FOR EXPLAINING FLOWS IN NETWORKS , DESCRIBING THE VARIABLES THAT INFLUENCE MOVEMENTS, AND FOR ULTIMATELY PREDICTING THE PERFORMANCE OF NETWORKS OF FACILITIES CARRYING LARGE NUMBERS OF VEHICLES.
54-2205	TO 2 (31)	$ 97	COLLECTION OF DATA ON WEEKEND AND RECREATIONAL TRAVEL.
54-2210	TO 3 (39)	$115	DETERMINE THE DIFFERENCES IN CHARACTERISTICS OF TRAFFIC FLOW BETWEEN SPACIOUS AND CONSTRICTED INTERCHANGES.
54-2213	DA 2 (61)	$ 79	EVALUATE POTENTIAL REVITALIZATIONS OF FRINGE-AREA ROADS BY CONVERSION TO ONE-WAY OPERATION.
55- 321	TO 06 (45)	$ 79	PROVISION OF DESIGN STANDARDS FOR WIDTH AS A FUNCTION OF DEVELOPMENT DENSITY RELATED TO OFF-STREET PARKING SUPPLY FOR MINOR RESIDENTIAL STREET.
55- 350	TO 04	$ 79	EFFECT OF PAVEMENT ON HIGHWAY CAPACITY AND ON LEVEL OF SERVICE PROVIDED.
55- 359	TO 09 (24)	$ 97	STUDY OF WHEN THE NET EFFECT OF TRAFFIC COMPOSITION AND LOADING IN A GIVEN ENVIRONMENTAL SITUATION REQUIRES ADDITIONAL LANES, OR WIDER LANES, OR WIDER SHOULDERS, ETC.
55-2206	TO 2 (31)	$115	DETERMINE THE SENSITIVITY OF ASSIGNED TRAFFIC TO CHANGES IN TRIP DISTRIBUTION AS CALCULATED BY MATHEMATICAL MODELS.
55-2207	TO 2 (31)	$ 97	DEVELOP A TECHNIQUE FOR ESTIMATING THE MOVEMENT OF TRAFFIC IN A SMALL AREA AT HIGH SPEED.

Note. All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 2-3 PROJECT STATEMENTS

OPERATION OF STREETS AND HIGHWAYS DURING NIGHT-TIME AND POOR VISIBILITY PERIODS

CODE NO. — SOURCE — COST

22- 359 — TC 09 (24) — $ 97
STUDY OF WHEN THE NET EFFECT OF TRAFFIC COMPOSITION AND LOADING IN A GIVEN ENVIRONMENTAL SITUATION REQUIRES ADDITIONAL LANES, OR WIDER LANES, OR WIDER SHOULDERS, ETC.

22- 423 — D A02 (61) — $115
DETERMINATION OF DRIVER STOPPING DISTANCE TO BE USED AS A BASIS FOR MINIMUM SIGHT DISTANCE CRITERIA FOR THE DESIGN OF HIGHWAYS. INFORMATION IS NEEDED FOR VARIOUS TYPES OF PAVEMENT, FOR DIFFERENT SIZES AND TYPES OF TIRES, AND FOR WET AND DRY PAVEMENTS.

22- 726 — TO 01 — $169
DETERMINATION OF THE OPTIMUM ECONOMIC DESIGN FOR ILLUMINATION LEVEL AND UNIFORMITY OF FREEWAY LIGHTING, RELATED TO ACCIDENT OCCURRENCE.

22- 730 — TO 01 — $115
EVALUATE EXISTING LIGHTING ON URBAN INTERSTATE FREEWAYS AND DEVELOP PRACTICAL ECONOMIC IMPROVEMENTS TO MEET OPTIMUM STANDARDS.

22- 731 — TO 01 — $ 97
ESTABLISH PROPER DESIGN FOR ADAPTATION LEVEL AND INTERIOR TUNNEL ILLUMINATION FOR OPTIMUM SAFETY AND TRAFFIC EFFICIENCY.

22- 732 — TC 01 — $133
DETERMINATION OF TRAFFIC SAFETY ON FREEWAYS RELATED TO LOCATION OF LIGHTING AND SIGN STRUCTURES.

22- 733 — TO 01 — $ 97
MEASUREMENT OF PAVEMENT DIRECTIONAL BRIGHTNESS FACTORS FROM TYPICAL VIEWING ANGLES AND LUMINAIRE PLACEMENTS AND TO SUMMARIZE PRIOR INVESTIGATIONS.

22- 734 — TC 01 — $ 97
EXPAND AND CONSOLIDATE PRIOR STUDIES OF VISIBILITY UNDER FOG AND RAIN CONDITIONS BY SPECIAL LIGHTING.

22- 735 — TC 01 — $ 97
EVALUATE DIFFERENT CLASSES OF URBAN STREETS BY ACCIDENT RATES VERSUS UNIFORMITY AND LEVELS OF ILLUMINATION.

34-1168 — INT — $ 97
DETERMINE THE BEST TYPE OF STREET LIGHTING FOR FREEWAYS.

40- 237 — MCST — $115
DETERMINATION OF THE COST AND PERFORMANCE LEVEL OF NIGHTTIME MAINTENANCE OPERATIONS.

40- 277 — M 05 (62) — $ 97
DETERMINATION OF THE EFFECT OF TRAFFIC MOVEMENT ON THE SNOW & ICE MELTING PROCESS AND THE MINIMUM HEAT NECESSARY TO KEEP TRAFFIC MOVING.

41- 228 — MCST (62) — $ 61
OPTIMIZATION OF ILLUMINATION ON SNOWPLOWING VEHICLES.

53- 35 — SC 8 — $ 97
INVESTIGATION OF NUCLEAR MATERIALS AS LIGHT SOURCES FOR ILLUMINATION OF HIGHWAY SIGNS AND THEIR RELATIVE SAFETY IN USE.

53- 256 — MOST — $ 97
INVESTIGATION OF NUCLEAR DEVICES, SENSITIVE TO TEMPERATURE CHANGE, WHICH WOULD ACTIVATE WARNING SIGNALS AT TIME OF ICY, SNOWY, AND FROSTY CONDITIONS.

CODE NO. — SOURCE — COST

53- 327 — TC 11 — $100
STUDY OF METHODS OF ALERTING DRIVERS TO CHANGES IN CONDITIONS, DETERMINATION OF DRIVER INFORMATION NEEDED FOR SATISFACTORY DRIVING, AND EFFECT OF VARIOUS KINDS OF DISTRACTION UPON THE TRANSMISSION OF INFORMATION TO THE DRIVER.

53- 331 — TC 03 — $109
INVESTIGATION OF POSSIBILITY OF USING TELEVISION MONITOR DEVICE IN AUTOMOBILES FOR PENETRATING FOG.

53- 368 — TC 12 — $115
STUDY OF VEHICLE STOPPING CHARACTERISTICS AT NIGHT IN ORDER TO ESTABLISH A DESIGN STOPPING SIGHT DISTANCE. ANALYSIS OF OPERATIONAL FACTORS SUCH AS OBJECT, HEADLIGHT BEAM, ROADWAY GEOMETRICS, AND SAFETY FACTORS IN ORDER TO PROPOSE A MAXIMUM NIGHT SPEED LIMIT.

53- 373 — TC 06 (45) — $ 61
STUDY OF NEED OF REDUCING SPEED LIMIT THROUGH SIGNS ON PARTS OF THE INTERSTATE SYSTEM DURING HAZARDOUS WEATHER.

53- 374 — TC 13 (45) — $145
DEVELOPMENT OF WARRANTS FOR LIGHTING FOR INTERCHANGES ON CONTROLLED-ACCESS HIGHWAYS TO REDUCE ACCIDENTS.

53- 379 — TO 06 (45) — $115
DETERMINATION OF HOW TO EFFECTIVELY DELINEATE OR ILLUMINATE OBSTRUCTIONS LOCATED WITHIN A ROADWAY IN ORDER THAT A NIGHT DRIVER MIGHT READILY COMPREHEND THE OBJECT.

53- 402 — TC 10 — $ 97
DETERMINATION OF HOW TO DETECT STOPPED VEHICLES, HOW TO APPROACH THEM UNDER SEVERE AND LIMITED OPERATING CONDITIONS, AND WHAT EQUIPMENT & ORGANIZATION ARE NECESSARY TO MOVE OR REMOVE THE STOPPAGE.

53- 729 — TC 01 — $ 85
DETERMINE SIGNIFICANT FACTS REGARDING USE OF ILLUMINATION FOR HIGHWAY TRAFFIC GUIDE AND CONTROL SIGNS.

53-1014 — INT — $115
EVALUATE IMPROVEMENT OF NIGHTTIME VISIBILITY PROVIDED BY VEHICLE HEADLIGHTS.

53-1029 — INT — $115
DEVELOP STANDARDS TO IMPROVE PRESENT RED REAR LIGHTING TO INFORM FOLLOWING DRIVERS OF VEHICLE MOVEMENTS IN LEAD VEHICLE.

53-1134 — INT — $ 97
DEVELOP DEVICES TO WARN MOTORISTS OF DANGERS ON HIGH-SPEED HIGHWAYS.

53-2209 — TO 3 (39) — $ 97
EVALUATE EFFECT OF SIGHT DISTANCE ON TRAFFIC OPERATIONS IN THE VICINITY OF FREEWAY RAMP TERMINALS.

53-2212 — TC 3 (39) — $115
DETERMINE OPERATION EFFECT OF SIGN PLACEMENT ON THE TRAFFIC STREAM.

90-1169 — INT — $115
STUDY IMPROVED NIGHTTIME VISIBILITY ON HIGHWAYS BY BETTER LIGHT REFLECTANCE AND MARKINGS.

Note: All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 2-4 PROJECT STATEMENTS

MAINTENANCE TECHNIQUES AND EQUIPMENT COMPATIBLE WITH OPERATING REQUIREMENTS ON HIGH-SPEED EXPRESSWAYS

CODE NO.	SOURCE	COST
22-1006	INT	$169
EVALUATE HIGHWAY DESIGN FEATURES–SUCH AS IRREGULAR OR NARROW TURF AREAS, STEEP SLOPES, INACCESSIBLE AREAS, ETC. TO PERMIT MECHANIZATION OF MAINTENANCE ACTIVITIES SUCH AS MOWING, CLEANING, AND PAINTING. THE RESULTANT USE OF HAND LABOR IS COSTLY AND OFTEN DANGEROUS.		
27- 292	M 10 (62)	$ 97
DEFINITION OF CRITERIA AND TYPE OF APPURTENANCES TO BE USED FOR MAINTENANCE FACILITIES FOR LARGE, LONG-SPAN BRIDGES. INITIAL CONSTRUCTION SHOULD TAKE INTO ACCOUNT NEED FOR MAINTENANCE FACILITIES.		
31- 235	MOST (62)	$115
IMPROVEMENT OF TECHNIQUES AND EQUIPMENT FOR PATCHING BITUMINOUS SURFACES.		
31- 241	MOST	$100
EXPLORATION OF FEASIBILITY OF PUMPING ASPHALTIC PATCHING MATERIAL BY A PNEUMATIC METHOD.		
40- 182	MOST (62)	$100
DEVELOPMENT OF NEW PAVEMENT PATCHING MATERIALS, CAPABLE OF BEING PLACED WITH RAPIDITY USING MINIMUM EQUIPMENT.		
40- 204	MOST	$100
DEVELOPMENT OF FAST-DRYING EFFECTIVE TRAFFIC PAINT AND PRACTICAL PRE-PAINTING, PREPARATION OF PAVEMENT SURFACES.		
40- 209	MOST (62)	$ 79
IMPROVEMENT OF METHODS FOR DETERMINING THE OPTIMUM TIME FOR REHABILITATION OF EXISTING PAVEMENTS.		
40- 217	MOST	$115
DEVELOPMENT OF NEW FAST AND INEXPENSIVE EROSION CONTROL MATERIALS FOR HIGHWAY MAINTENANCE.		
40- 252	MOST	$ 79
STUDY OF PRESENT COMMUNICATION REQUIREMENTS FOR HIGHWAY MAINTENANCE AND DEVELOPMENT OF GUIDELINES FOR OPTIMUM COMMUNICATION FACILITIES.		
40- 300	M 2	$ 61
STUDY OF FEASIBILITY OF FLUSH-MOUNTING HIGHWAY DELINEATORS TO ELIMINATE THE MAINTENANCE PROBLEM PRESENTED BY CONVENTIONAL TYPE DELINEATORS.		
40- 561	FSC04	$115
DETERMINATION OF EFFECT UPON THE ROAD USER OF MAINTENANCE OPERATIONS.		
40-1002	INT	$ 97
DETERMINE STANDARDS FOR TRAFFIC CONTROL DURING MAINTENANCE OPERATIONS, BECAUSE INCREASING TRAFFIC VOLUMES MAKE MAINTENANCE OPERATIONS DIFFICULT, EXPENSIVE, AND DANGEROUS TO EMPLOYEES AND HIGHWAY USERS.		
40-1031	INT	$ 85
ESTABLISH IMPROVED CONSTRUCTION AND TRAFFIC CONTROL TECHNIQUES FOR HANDLING RESURFACING PROJECTS ON BUSY URBAN HIGHWAYS.		
40-1165	INT	$124
DETERMINE OPTIMUM MANPOWER AND EQUIPMENT USED IN SNOW REMOVAL OPERATIONS AND PERFORM SYSTEMS ANALYSIS IN SCHEDULING WORK CREWS AND DETERMINING TIME-COST FACTORS RELATIVE TO HIRING EXTRA MEN AND EQUIPMENT.		
40-1166	INT	$115
DEVELOP BETTER SNOW AND ICE REMOVAL TECHNIQUES AND DESIGN HIGHWAY CROSS SECTIONS TO MINIMIZE DRIFTING.		
41- 220	MOST (62)	$145
DEVELOPMENT OF NEW LITTER PICKUP EQUIPMENT WHICH WOULD PERFORM THE SAME FUNCTION AS A VACUUM CLEANER.		
41- 221	MOST (62)	$124
DEVELOPMENT OF ECONOMICAL WASHING EQUIPMENT FOR SIGN CLEANING WITHOUT TRAFFIC BLOCKAGE.		
41- 223	MOST (62)	$124
DEVELOPMENT OF AN EFFICIENT RIGID PAVEMENT JOINT CLEANING MACHINE.		
41- 243	MOST	$ 79
IMPROVEMENT OF REMOTE CONTROL METHODS OF MOWING FOR APPLICATION TO OTHER MAINTENANCE OPERATIONS,ESPECIALLY ON THE INTERSTATE SYSTEM.		
41- 279	M 05	$115
EVALUATION OF EXISTING BURIED-PIPE AND INFRARED ICE-MELTING SYSTEMS TO DETERMINE MINIMUM HEAT REQUIREMENTS AND WEAKNESSES IN THE DESIGN.		
41- 281	M 05 (62)	$115
EVALUATION OF TIPPMANN'S METHOD OF SNOW MELTING.		
41-1038	INT	$115
ESTABLISH THE MOST ECONOMICAL SIZE EQUIPMENT FOR SIGN AND PAINT STRIPING MAINTENANCE OPERATIONS.		

Note: All costs in thousands of dollars.

PROBLEM AREA 2-5 PROJECT STATEMENTS

SURVEILLANCE AND CONTROL OF TRAFFIC FLOW ON URBAN STREET AND HIGHWAY SYSTEMS

CODE NO.	SOURCE	COST
15- 578	FSC05	$ 97
IMPROVEMENT OF TECHNIQUES FOR VALUATION OF URBAN STREETS SYSTEMS AND STUDY OF INVESTMENTS IN TYPICAL URBAN AREAS.		
15- 579	FSC05	$115
DEVELOPMENT OF A SUFFICIENCY RATING SYSTEM OR INDEX OF ADEQUACY FOR URBAN STREETS.		
22- 318	TO 03 (45)	$ 97
MINIMIZATION OF LANE CHANGES AND MERGING OF TRAFFIC TO FEWER LANES AT INTERCHANGES.		
22- 319	TO 03 (45)	$ 61
PROVISION OF A GUIDE FOR MINIMUM SPACING OF CROSSOVERS (MEDIAN OPENINGS) ON DIVIDED HIGHWAYS WITHOUT CONTROL OF ACCESS.		
22- 320	TO 03 (45)	$ 79
DEVELOPMENT OF A DESIGN FOR MEDIAN FOR SURFACE HIGHWAYS IN URBAN AREAS, PERMITTING GOOD ACCESS TO ABUTTING PROPERTY AND ACHIEVING HIGH CAPACITY FOR THROUGH MOVEMENTS AND MAXIMUM SAFETY.		
22- 424	D A03 (61)	$ 97
INCREASE OF KNOWLEDGE REGARDING THE DESIGN AND OPERATION OF 2-LANE TURNING ROADWAYS, INCLUDING THE DETERMINATION OF GEOMETRIC CRITERIA AND THE REEVALUATION OF EXISTING DESIGN STANDARDS FOR 2-LANE LEFT TURNS AT GRADE.		
22- 425	D A02 (61)	$ 79
DETERMINATION OF BEST TYPE OF ACCELERATION AND DECELERATION LANES APPLICABLE TO AT-GRADE INTERSECTIONS AND INTERCHANGE RAMP ENTRANCE AND EXIT TERMINALS.		
22-2059	INT	$ 70
DEVELOP CRITERIA FOR CONTROL OF EXPRESSWAY ACCESS BY FUNCTIONAL DESIGN AND INCORPORATION OF SURVEILLANCE SYSTEMS TO PREVENT OVERLOADS AND BREAKDOWN OF TRANSPORT FACILITIES.		
51- 13	UTP14	$ 97
CONTINUATION OF ANALYSIS OF ROADSIDE OBSTACLE RESEARCH BEGUN BY MR. STONEX, WITH EVENTUAL DEVELOPMENT OF AN ANALYTIC MODEL USEFUL FOR DESIGN REQUIREMENTS.		
51- 232	MOST	$ 97
EVALUATION OF VARIOUS MEANS OF PROVIDING EFFECTIVE, EMERGENCY COMMUNICATION SYSTEMS ON CONTROLLED ACCESS HIGHWAYS.		
51- 256	MOST	$ 97
INVESTIGATION OF NUCLEAR DEVICES, SENSITIVE TO TEMPERATURE CHANGE, WHICH WOULD ACTIVATE WARNING SIGNALS AT TIME OF ICY, SNOWY, AND FROSTY CONDITIONS.		
51- 390	TC 06 (45)	$130
STUDY OF THE LIKELIHOOD OF ACCIDENTS IN TERMS OF THE PROXIMITY OF FIXED OBJECT IN ORDER TO DESIGN SAFER STRUCTURES THAT MUST BE KEPT CLOSER TO THE TRAVEL WAYS AND TO ESTABLISH SAFE OFFSETS.		
52- 327	TC 11	$100
STUDY OF METHODS OF ALERTING DRIVERS TO CHANGES IN CONDITIONS, DETERMINATION OF DRIVER INFORMATION NEEDED FOR SATISFACTORY DRIVING, AND EFFECT OF VARIOUS KINDS OF DISTRACTION UPON THE TRANSMISSION OF INFORMATION TO THE DRIVER.		
52- 329	TC 11	$ 79
ANALYSIS OF THE DRIVER'S ABILITY TO ACQUIRE INFORMATION BY SENSING RELEVANT DATA FROM THE ENVIRONMENT ABOUT VELOCITY, HEADWAY, AND ACCELERATION. STUDY OF HIS METHODS OF SENSING AND DECISION MAKING IN EMERGENCY SITUATIONS. DEVELOP MODELS SHOWING HOW INFORMATION ACQUISITION WILL AFFECT FLOW, DENSITY, AND HIGHWAY SAFETY.		
52- 330	TC 03	$ 97
IDENTIFICATION AND MEASUREMENT OF SIGNIFICANT DRIVER STIMULI, MOTIVATIONS, AND REACTIONS AFFECTING FREEWAY DRIVING.		
52- 343	TC 09 (24)	$ 97
EFFECT OF SPEED ON A DRIVER'S INFORMATION RECEPTION CAPABILITIES.		
52- 352	TC 12	$ 85
DETERMINATION OF FACTORS WHICH INFLUENCE A MOTORIST'S SELECTION OF HIS DESIRED TRAVEL LANE.		
53- 348	TO 04	$ 97
DETECTION OF REASONS FOR UNBALANCED USE OF URBAN ARTERIAL LANES BY DRIVERS AND DEVELOPMENT OF SUGGESTED PROCEDURES FOR MORE BALANCED USE.		
53- 356	TC 5	$ 97
STUDY OF FACTORS AFFECTING GAP AND LAG ACCEPTANCE UNDER TWO-WAY STOP AND YIELD CONTROL AND SIMULATION OF MODELS FOR ANALYSIS OF THESE CONTROLS.		
53- 360	TC 04	$ 79
DETERMINATION OF WHETHER THE BANNING OF LEFT TURNS AT INTERSECTIONS ON TWO-WAY STREETS IS TRULY PRACTICAL AND IF NOT, ESTABLISHMENT OF THE FEASIBILITY OF INSTALLATION OF MULTIPHASE SIGNALIZATION TO ACCOMMODATE THE TURNS.		
53- 362	TO 04	$ 61
DETERMINATION OF FEASIBILITY OF COORDINATING ESSENTIAL MIDBLOCK TRAFFIC ENTRANCES WITH THE OVERALL ARTERIAL SIGNAL PROGRESSION.		
53- 363	TC 04	$115
COMPARISON OF THE EFFICIENCY, AS A GROUP, OF SEVERAL STREETS MAKING UP A TRAFFIC CORRIDOR, WHEN OPERATING ONE-WAY AS COMPARED TO TWO-WAY.		
53- 364	TO 04	$ 79
DEVELOPMENT OF PROCEDURES FOR DESCRIBING THE LEVEL OF SERVICE PROVIDED BY TWO-WAY STOP-CONTROLLED INTERSECTIONS UNDER ANY SPECIFIED VOLUME CONDITIONS.		
53- 365	TC 10	$169
DEVELOPMENT OF DESIGN CRITERIA FOR TRAFFIC CONTROL SYSTEMS TO CONTROL THE DISTRIBUTOR SYSTEM AS A FUNCTION OF THE FREEWAY DEMAND.		
53- 367	TC 10	$145
DETERMINATION OF HOW TO DISTRIBUTE TRAFFIC OVER FREEWAYS AND ARTERIAL STREETS TO BEST ACCOMMODATE PEAK-HOUR MOVEMENTS OF TRAFFIC.		
53- 373	TC 06 (45)	$ 61
STUDY OF NEED OF REDUCING SPEED LIMIT THROUGH SIGNS ON PARTS OF THE INTERSTATE SYSTEM DURING HAZARDOUS WEATHER.		
53- 378	TC 05 (45)	$ 97
DETERMINATION OF THE BEST USE OF GREEN ARROWS FOR SPLIT PHASE SIGNAL OPERATION TO PROVIDE UNIFORM OPERATION WITH MINIMAL VEHICULAR DELAY AND CONFLICTS.		
53- 385	TC 05	$ 43
DETERMINATION OF THE AMOUNT OF DELAY THAT PEDESTRIAN TRAFFIC CAUSES VEHICULAR TRAFFIC AT A FOUR-WAY STOP CONTROLLED INTERSECTION.		
53- 402	TC 10	$ 97
DETERMINATION OF HOW TO DETECT STOPPED VEHICLES, HOW TO APPROACH THEM UNDER SEVERE AND LIMITED OPERATING CONDITIONS, AND WHAT EQUIPMENT & ORGANIZATION ARE NECESSARY TO MOVE OR REMOVE THE STOPPAGE.		
53- 429	D A02 (61)	$ 61
IDENTIFICATION OF CRITERIA FOR THE DESIGN AND OPERATION OF REVERSIBLE FREEWAY ROADWAYS.		
53-2062	INT	$133
WAYS AND MEANS OF DIVERTING THAT PORTION OF PEAK TRAFFIC WHICH WOULD CONGEST THE FREEWAYS BUT ALLOW EXPRESS BUSES ENTRY, AND DEVISE WAYS TO IMPROVE PEAK-HOUR FLOWS ON PARALLEL SURFACE FACILITIES. METHODS OF INFORMING MOTORISTS OF ALTERNATE ROUTES TO THEIR DESTINATIONS.		
54- 357	TC 09 (24)	$ 97
STUDY OF THE RELATIONSHIP BETWEEN TRAFFIC FLOW AND THE SPEED AT WHICH CHANGES IN DENSITY, SPEED, OR FLOW ARE PROPAGATED ALONG THE ROADWAY. THE OBJECT IS TO ESTIMATE THE PROBABLE EFFECT OF ALTERNATIVE COURSES OF ACTION IN PREVENTING HIGH ACCIDENT POTENTIAL INHERENT IN SHOCK WAVES.		
54- 361	TO 04	$ 97
DETERMINATION OF THE EFFECTIVENESS OF CONTINUOUS RESERVED LEFT-TURN LANE.		
54- 366	TC 10	$ 97
DEVELOPMENT OF MEANS FOR REDUCING THE SPACE REQUIRED BETWEEN VEHICLES WITHOUT SACRIFICING SAFETY OR SPEED.		

Note: All costs in thousands of dollars.

52- 358 TC 09 (24) $ 97
STUDY OF CAR-FOLLOWING BEHAVIOR, INCLUDING THE PERCEPTION BY THE DRIVER OF THE ACTIONS OF THE VEHICLE AHEAD AND THE INFLUENCE ON HIS DECISIONS BY THESE ACTIONS. THE OBJECT IS TO IMPROVE THE DESIGN OF VISUAL AND ELECTRONIC DISPLAYS WHICH ASSIST DRIVERS TO MEASURE THEIR VELOCITY, RELATIVE TO THE CAR AHEAD.

52- 404 TC 10 $ 97
STUDY OF DATA ON ACTUAL FREEWAY BLOCKAGES CAUSED BY DISTRACTIONS AND STUDY OF EFFECT OF DISTRACTIONS ON ACCIDENT POTENTIAL.

54-2205 TC 2 (31) $ 97
COLLECTION OF DATA ON WEEKEND AND RECREATIONAL TRAVEL.

54-2206 TC 2 (31) $115
DETERMINE THE SENSITIVITY OF ASSIGNED TRAFFIC TO CHANGES IN TRIP DISTRIBUTION AS CALCULATED BY MATHEMATICAL MODELS.

54-2207 TC 2 (31) $ 97
DEVELOP A TECHNIQUE FOR ESTIMATING THE MOVEMENT OF TRAFFIC IN A SMALL AREA AT HIGH SPEED.

84-2028 INT $115
DEVELOP GUIDELINES FOR AUTOMATIC VEHICLE CONTROLS TO DEVELOP SAFER OPERATIONS ON MOTORWAYS UNDER HIGH-CAPACITY CONDITIONS.

TABLE D-3 (*Continued*)

PROBLEM AREA 3-1 PROJECT STATEMENTS

AESTHETIC CONSIDERATIONS IN THE DESIGN, MAINTENANCE, AND OPERATION OF HIGHWAYS

CODE NO. SOURCE COST

11- 258 MOST $ 70
DEVELOPMENT OF GUIDELINES FOR MAINTENANCE OPERATIONS AND SERVICES TO IMPROVE PUBLIC RELATIONS AND WIN PUBLIC SUPPORT OF THE HIGHWAY PROGRAM.

11- 621 FSC01 $ 97
DETERMINATION OF TECHNIQUES OF LAND USE CONTROL ALONG HIGHWAYS, TAKING INTO ACCOUNT THE COSTS, EFFECTIVENESS, AND PUBLIC ACCEPTANCE OF LAND USE GUIDANCE MEASURES.

11- 656 FSC07 $ 97
DETERMINATION OF AN EFFECTIVE METHOD OF ADMINISTRATIVE RESPONSIBITY FOR URBAN HIGHWAY EXTENSIONS, SO THAT THOSE AFFECTED BY THE CONSEQUENCES OF HIGHWAY IMPROVEMENT ARE CONSIDERED.

11- 664 FSC08 $115
PROTECTION OF NATURAL LANDSCAPE BY LEGAL OR ADMINISTRATIVE DEVICES.

11- 709 L 05 $ 97
STUDY OF THE CAPABILITY OF HIGHWAY AND OTHER PUBLIC AGENCIES TO ESTABLISH AND ADMINISTER CORRIDOR AREA LAND USE CONTROLS AND EXPLORATION OF THE RANGE OF AUTHORITY TO ACHIEVE DESIRED SCENIC CORRIDOR DEVELOPMENT.

13- 10 UTP03 $100
REAPPRAISAL OF RELOCATION COSTS POLICY, EVALUATION OF BENEFITS TO COMMUNITY BY REDUCING DISPLACEE OPPOSITION, AND FORMULATION OF A RELOCATION COSTS CONCEPT WHICH WILL RESULT IN GREATER PUBLIC ACCEPTANCE OF DECISIONS.

13- 605 FSC08 $115
DETERMINATION OF EQUITABILITY OF TREATMENT TO RESIDENTS AND BUSINESSES RELOCATED FROM HIGHWAY RIGHT-OF-WAY AND OF MANNER TO EASE DISLOCATIONS CAUSED BY HIGHWAY PROGRAMS.

13- 617 FSC08 $ 61
RELATIONSHIP BETWEEN THE VALUE OF SCENIC EASEMENT AND THE VALUE OF THE FEE SIMPLE TITLE OF THE PROPERTY.

13- 680 LS 02 $ 97
DETERMINATION OF RULES FOR ACQUISITION AND VALUATION OF AIR RIGHTS AND EASEMENTS FOR SCENIC PURPOSES.

15- 622 FSC01 $ 85
MEASUREMENT OF THE CONSEQUENCES OF RIGHT-OF-WAY DISPLACEMENT IN TERMS OF BOTH COMPENSABLE AND NON-COMPENSABLE LOSSES AND RECOMMENDATION OF AMELIORATIVE PROCEDURES FOR INDIVIDUAL INCONVENIENCE.

22- 315 TC 03 (39) $ 79
DETERMINATION OF BEST DESIGN FOR MEDIANS ON URBAN EXPRESSWAYS WHERE RIGHT OF WAY IS COSTLY OR OTHERWISE LIMITED.

22-1006 INT $169
EVALUATE HIGHWAY DESIGN FEATURES-SUCH AS IRREGULAR OR NARROW TURF AREAS, STEEP SLOPES, INACCESSIBLE AREAS, ETC. TO PERMIT MECHANIZATION OF MAINTENANCE ACTIVITIES SUCH AS MOWING, CLEANING, AND PAINTING. THE RESULTANT USE OF HAND LABOR IS COSTLY AND OFTEN DANGEROUS.

22-1034 INT $115
DEVELOP ECONOMICAL GUIDELINES AND TECHNIQUES FOR THE IMPROVEMENT OF HIGHWAY AESTHETICS.

22-2004 INT $133
DEVELOP GUIDELINES ON SUCH MATTERS AS WHEN TO DEPRESS OR ELEVATE HOW TO RELATE FREEWAYS TO PARKING FACILITIES HOW TO COORDINATE WITH PUBLIC TRANSPORTATION FACILITIES IN HIGHWAYS OR OTHERWISE AIR RIGHTS VEHICULAR-PEDESTRIAN SEPARATIONS ROAD PLANS RELATED TO URBAN RENEWAL PROGRAM.

24- 400 TC 07 (25) $109
DETERMINATION OF IMPORTANCE OF ESTHETICS AS A TRAFFIC SERVICE QUALITY AND DETERMINATION OF A TECHNIQUE FOR MEASURING ITS IMPORTANCE.

24- 451 D A 5 $ 97
ESTABLISH CRITERIA FOR EVALUATION OF FUNCTION, DESIGN, AND LOCATION OF HIGHWAY REST AREAS.

24- 452 D A05 $ 97
ACHIEVEMENT OF CONTROL OF UNSIGHTLY JUNKYARDS AND VEHICLE GRAVEYARDS BY LEGISLATION.

24- 455 D A05 $ 97
STUDY OF THE EFFECT THAT VARIOUS FORMS OF LANDSCAPE DEVELOPMENT HAVE ON PROPERTY VALUES ADJACENT TO HIGHWAYS.

24- 607 FSC08 $ 85
EFFECTIVENESS OF FEDERAL PROVISIONS AFFECTING OUTDOOR ADVERTISING AND IDENTIFICATION OF DIFFERING TECHNIQUES FOR CONTROL OF OUTDOOR ADVERTISING.

24- 665 FSC08 $100
CONTROL OF ESTHETICS ALONG HIGHWAY RIGHT- OF-WAY UNDER POLICE POWER.

24- 672 LS 04 $ 85
STUDY OF SOVEREIGN POWERS OF THE STATE AS THEY APPLY TO LANDS AND LANDUSE IN ROADSIDE AREAS AROUND EXPRESSWAY INTERCHANGES.

24-1035 INT $ 85
DEVELOP GUIDELINES FOR REDUCING MAINTENANCE COSTS SINCE SLOPE EROSION, MOWING 2/1 SLOPES, DITCH CLEANING AND OTHER ROADSIDE MAINTENANCE ACTIVITIES ARE INCREASINGLY COSTLY ON WIDE RIGHTS-OF-WAY YET INTEREST IN AESTHETICS MAKES GOOD MAINTENANCE MANDATORY.

24-2036 INT $115
DETERMINE CHARACTERISTICS, APPLICATION, AND DESIRABILITY OF VARIOUS TYPES OF VEGETATION IN DIFFERENT GEOGRAPHIC LOCATIONS.

70- 608 FSC08 $ 79
STUDY OF THE USE OF HIGHWAY RIGHT-OF-WAY BY UTILITIES AND OF PROBLEMS OF REMOVING UTILITIES FROM RIGHT-OF-WAY PROPERTY.

70- 616 FSC08 $ 79
STUDY OF GUIDELINES AND METHODS FOR ESTABLISHING HIGHWAY ADVERTISING RIGHTS.

82- 538 FSC02 $ 85
QUANTIFICATION OF NONUSER BENEFITS OF A HIGHWAY BY MEANS OF AN INDEX OF IMPACT.

84- 722 UTP03 $100
DETERMINE THE ROLE OF AESTHETICS AS A COMMUNITY DECISION-MAKING FACTOR IN ALTERNATIVE TRANSPORTATION SYSTEMS SELECTION, DESIGN AND LOCATION.

Note All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 3-2 PROJECT STATEMENTS

IMPACT OF VARIOUS TYPES OF DESIGN FEATURES OF HIGHWAYS UPON ENVIRONMENTAL VALUES

CODE NO.	SOURCE	COST	PROJECT STATEMENT
22- 697	L 05	$ 79	STUDY OF VARIOUS TYPES OF GEOMETRIC DESIGN USE IN CLOSURE OF STREETS AND HIGHWAYS FOR CONTROL OF ACCESS AS THEY AFFECT REASONABLENESS OF ACCESS AND CORRELATION WITH THE JUDICIAL DETERMINATION OF WHETHER A COMPENSABLE INJURY TO ACCESS HAS OCCURRED.
22-1025	INT	$ 79	EVALUATE BUILD-UP OF INTERCHANGE AREAS AS IT AFFECTS INTERCHANGE OPERATION AND OFTEN THWARTS DESIGN AND OPERATING PLANS.
22-2029	INT	$115	DEVELOP STANDARDS SUITABLE FOR USE IN ENVIRONMENTS WHERE RECOGNITION MUST BE GIVEN TO THE HIGHER COSTS OF INTERFERENCE WITH ESTABLISHED LAND USES, AND PUBLIC UTILITIES. CONNECTIONS TO STREET SYSTEMS MUST CONSIDER THE SAFETY OF PEDESTRIANS AND SLOWER STREET TRAFFIC.
22-2042	INT	$ 97	DEVELOP DESIGN STANDARDS FOR JUNIOR EXPRESSWAYS TO LESSEN RIGHT-OF-WAY AND CONSTRUCTION COST REQUIREMENTS, AS WELL AS DETRIMENTAL IMPACT ON LAND USES AND OTHER CONSIDERATIONS.
24- 612	FSC08	$ 61	INVESTIGATION OF POSSIBLE PUBLIC ACTION INITIATED TO ASSURE THAT BUSINESSES LOCATED NEAR HIGHWAYS SATISFY NEEDS OF HIGHWAY USERS.
24- 665	FSC08	$100	CONTROL OF ESTHETICS ALONG HIGHWAY RIGHT- OF-WAY UNDER POLICE POWER.
24- 672	LS 04	$ 85	STUDY OF SOVEREIGN POWERS OF THE STATE AS THEY APPLY TO LANDS AND LANDUSE IN ROADSIDE AREAS AROUND EXPRESSWAY INTERCHANGES.
24- 709	L 05	$ 97	STUDY OF THE CAPABILITY OF HIGHWAY AND OTHER PUBLIC AGENCIES TO ESTABLISH AND ADMINISTER CORRIDOR AREA LAND USE CONTROLS AND EXPLORATION OF THE RANGE OF AUTHORITY TO ACHIEVE DESIRED SCENIC CORRIDOR DEVELOPMENT.
24- 712	L 05	$ 70	ANALYSIS OF THE NATURE AND EXTENT OF IMPACT OF PRIVATE LEGAL CONTROLS ON HIGHWAY IN ORDER TO DETERMINE WHEN REGULATION OF ROADSIDE LANDS MIGHT BE LEFT TO PRIVATE MEANS.
24-1034	INT	$115	DEVELOP ECONOMICAL GUIDELINES AND TECHNIQUES FOR THE IMPROVEMENT OF HIGHWAY AESTHETICS.
55- 321	TC 06 (45)	$ 79	PROVISION OF DESIGN STANDARDS FOR WIDTH AS A FUNCTION OF DEVELOPMENT DENSITY RELATED TO OFF-STREET PARKING SUPPLY FOR MINOR RESIDENTIAL STREET.
55- 400	TC 07 (25)	$109	DETERMINATION OF IMPORTANCE OF ESTHETICS AS A TRAFFIC SERVICE QUALITY AND DETERMINATION OF A TECHNIQUE FOR MEASURING ITS IMPORTANCE.
55- 401	TU 04	$115	DETERMINATION AND EVALUATION OF ALL MEANS OF MAKING TRANSIT SERVICES SPEEDY AND ATTRACTIVE IN THE MORE CONGESTED URBAN AREAS.
70- 700	L 05	$ 79	CLARIFICATION OF THE EXTENT TO WHICH FRONTAGE ROADS SATISFY THE REQUIREMENT THAT ROADSIDE LAND NOT BE DEPRIVED OF REASONABLE ACCESS TO ADJACENT HIGHWAYS.
81-2030	INT	$ 97	DEVELOP AN UP-TO-DATE COMPENDIUM OF ALL PERTINENT KNOWLEDGE CONCERNING THE BROAD SUBJECTS THAT INFLUENCE REGIONAL PLANNING. I. E. TRANSIT, DRAINAGE, ROADWAY DESIGN, PARKING, SEWERAGE, WATER SUPPLY, UTILITY SERVICES.
82- 453	D A05	$115	ESTABLISH PHYSICAL STANDARDS FOR STRUCTURES MAKING MULTIPLE USE OF HIGHWAY RIGHT-OF-WAY INCLUDING SAFETY, STRENGTH, VIBRATION, NOISE AND AIR POLLUTION.
82- 455	D A05	$ 97	STUDY OF THE EFFECT THAT VARIOUS FORMS OF LANDSCAPE DEVELOPMENT HAVE ON PROPERTY VALUES ADJACENT TO HIGHWAYS.
82- 529	FSC01	$ 97	DETERMINATION OF THE EFFECTS OF ADDING HIGHWAYS TO AN URBAN AREA WITH AN EXISTING HIGHLY DEVELOPED SYSTEM OF ROADWAYS, INCLUDING STUDY OF THE RELOCATION, TAX ROLLS, AND PUBLIC SERVICES.
82- 535	FSC01	$115	STUDY OF THE ECONOMIC AND SOCIAL EFFECTS OF HIGHWAYS ON NEIGHBORHOODS.
82- 544	FSC02	$115	UNDERSTANDING OF THE INFLUENCE OF HIGHWAY INVESTMENT ON PRIVATE AND OTHER PUBLIC INVESTMENT, REORGANIZATION OF LAND USES, RELATIONSHIP TO DEMAND IN GENERAL, AND THE RATE OF ECONOMIC GROWTH.
82- 623	FSC08	$ 97	DEVELOPMENT OF AN ECONOMIC MODELS TO SIMULATE HIGHWAY IMPACT IN ORDER TO DETERMINE THE EFFECTS OF TRANSPORTATION UPON ALTERNATIVE COMMUNITIES AND THEIR ECONOMIC ACTIVITIES.
82-2004	INT	$133	DEVELOP GUIDELINES ON SUCH MATTERS AS WHEN TO DEPRESS OR ELEVATE HOW TO RELATE FREEWAYS TO PARKING FACILITIES HOW TO COORDINATE WITH PUBLIC TRANSPORTATION FACILITIES IN HIGHWAYS OR OTHERWISE AIR RIGHTS VEHICULAR-PEDESTRIAN SEPARATIONS ROAD PLANS RELATED TO URBAN RENEWAL PROGRAM.
83- 4	UTP02 (13)	$ 97	DEVELOPMENT OF TECHNIQUES FOR ARTICULATING LAND USE PLANNING GOALS, FOR EVALUATING ALTERNATIVES, AND FOR FORMULATING A SCALE FOR RELATING COMMUNITY VALUES TO DEVELOPMENT FORM.
83- 518	FSC01	$ 70	DETERMINATION OF ECONOMIC FACTORS THAT UNDERLY RESIDENTIAL SITE SELECTIONS BY DEVELOPERS AND BY RESIDENTS.
83- 526	FSC01	$ 97	STUDY OF LAND DEVELOPMENT AND MOTOR-VEHICLE USES AT INTERCHANGE POINTS IN ORDER TO DEVELOP THE MOST DESIRABLE ZONING AND LAND USE CONTROL AT FUTURE INTERCHANGES.
83- 527	FSC01	$115	STUDY OF THE ROLE OF HIGHWAYS IN SHAPING LAND DEVELOPMENT AND USES.
84-2058	INT	$ 97	EVALUATE TECHNIQUES FOR CURTAILING LAND DEVELOPMENTS AS CONGESTED FACILITIES RESTRAIN TRAFFIC FLOWS.

Note: All costs in thousands of dollars.

TABLE D-3 (*Continued*)

PROBLEM AREA 3-3 PROJECT STATEMENTS

ACCOMMODATION OF MULTIPLE USE OF RIGHT-OF-WAY IN URBAN AREAS

CODE NO.	SOURCE	COST	
11- 613	FSC08	$115	STUDY OF UTILIZATION OF AIR RIGHTS ABOVE AND BELOW PUBLIC HIGHWAYS.
11- 714	L 05	$ 70	ANALYSIS OF THE STATE HIGHWAY DEPARTMENTS LEGAL POSITION WHEN IN POSSESSION OF LAND BEING USED FOR NON-HIGHWAY PRIVATE PURPOSES AND FORMULATION OF THE HIGHWAY AGENCYS MANAGEMENT RESPONSIBILITIES.
13- 680	LS 02	$ 97	DETERMINATION OF RULES FOR ACQUISITION AND VALUATION OF AIR RIGHTS AND EASEMENTS FOR SCENIC PURPOSES.
15- 575	FSC05	$ 85	RELATIONSHIP BETWEEN HIGHWAY DEVELOPMENT, PUBLIC SERVICES, AND TAX BASES.
15- 708	L 05	$ 85	STUDY OF CAPABILITY OF TAXES AND REGULATORY MEASURES TO CONTROL LAND USES ADJACENT TO HIGHWAYS.
24- 400	TU 07 (25)	$109	DETERMINATION OF IMPORTANCE OF ESTHETICS AS A TRAFFIC SERVICE QUALITY AND DETERMINATION OF A TECHNIQUE FOR MEASURING ITS IMPORTANCE.
24- 455	D A05	$ 97	STUDY OF THE EFFECT THAT VARIOUS FORMS OF LANDSCAPE DEVELOPMENT HAVE ON PROPERTY VALUES ADJACENT TO HIGHWAYS.
70- 685	L 05	$ 85	STUDY OF THE LEGAL PROBLEMS INVOLVED IN UTILIZATION OF AIR SPACE ABOVE AND BENEATH HIGHWAYS.
82- 453	D A05	$115	ESTABLISH PHYSICAL STANDARDS FOR STRUCTURES MAKING MULTIPLE USE OF HIGHWAY RIGHT-OF-WAY INCLUDING SAFETY, STRENGTH, VIBRATION, NOISE AND AIR POLLUTION.
82- 538	FSC02	$ 85	QUANTIFICATION OF NONUSER BENEFITS OF A HIGHWAY BY MEANS OF AN INDEX OF IMPACT.
82-2004	INT	$133	DEVELOP GUIDELINES ON SUCH MATTERS AS WHEN TO DEPRESS OR ELEVATE HOW TO RELATE FREEWAYS TO PARKING FACILITIES HOW TO COORDINATE WITH PUBLIC TRANSPORTATION FACILITIES IN HIGHWAYS OR OTHERWISE AIR RIGHTS VEHICULAR-PEDESTRIAN SEPARATIONS ROAD PLANS RELATED TO URBAN RENEWAL PROGRAM.
83- 516	FSC01	$ 85	STUDY OF FACTORS RELATED TO THE TOTAL NEEDS OF AN AREA WHICH WILL INSURE THAT HIGHWAY DEVELOPMENT WILL FIT THOSE NEEDS.
83- 524	FSC01	$115	STUDY OF THE EFFECT OF CHANGES IN LAND USE ON TRAFFIC AND TRANSPORTATION PATTERNS.
83- 526	FSC01	$ 97	STUDY OF LAND DEVELOPMENT AND MOTOR-VEHICLE USES AT INTERCHANGE POINTS IN ORDER TO DEVELOP THE MOST DESIRABLE ZONING AND LAND USE CONTROL AT FUTURE INTERCHANGES.
83- 527	FSC01	$115	STUDY OF THE ROLE OF HIGHWAYS IN SHAPING LAND DEVELOPMENT AND USES.
83- 621	FSC01	$ 97	DETERMINATION OF TECHNIQUES OF LAND USE CONTROL ALONG HIGHWAYS, TAKING INTO ACCOUNT THE COSTS, EFFECTIVINESS, AND PUBLIC ACCEPTANCE OF LAND USE GUIDANCE MEASURES.
83- 624	FSC01	$115	DETERMINATION OF OPTIMUM RATIO OF URBAN LAND USE FOR TRANSPORTATION TO TOTAL LAND AREA.
84- 546	FSC02	$ 79	STUDY OF MARGINAL COST OF TRAFFIC LANES RESERVED FOR RAPID TRANSIT.

Note: All costs in thousands of dollars.

TABLE D-4

ESTIMATED PROJECT COSTS, BY PROBLEM AREA

PROBLEM AREA [a]	PRIORITY [b]	PROJECT CODE NO.	EST. COST ($1,000)
1–1	1	31–253	79
		40–207	115
		40–267	169
		41–29	97
		41–30	97
		41–255	145
		64–107	79
		64–109	79
		All	*860*
	2	23–91	70
		25–112	79
		25–114	79
		25–115	97
		26–69	97
		33–1107	70
		34–76	97
		61–33	97
		61–72	97
		61–153	79
		62–97	61
		62–99	85
		62–100	97
		All	*1,105*
	3	26–463	133
		32–254	97
		34–1009	97
		41–183	97
		41–230	97
		All	*521*
	All		2,486
1-2	1	23–440	70
		55–2205	97
		54–2210	115
		All	*282*
	2	27–292	97
		27–431	100
		40–300	61
		40–304	79
		40–561	115
		41–279	115
		41–451	97
		51–1162	97
		All	*761*
	3	40–387	115
		40–1166	115
		41–1006	169
		51–388	61
		53–409	115
		64–1109	97
		All	*672*
	All		1,715
1–3	1	22–408	97
		22–434	115
		53–439	79
		53–2209	97
		55–353	115
		55–376	43
		55–2201	79
		54–2205	97
		All	*722*
	2	15–431	100
		15–649	97
		22–315	79
		22–359	97
		22–410	61
		22–422	85
		22–430	115
		22–2042	97
		53–425	79
		53–428	115
		53–432	85
		53–435	97
		53–436	97
		54–2210	115
		55–570	115
		83–713	61
		All	*1,495*
	3	15–583	97
		15–2097	97
		52–346	79
		All	*273*
	All		2,490
1–4	1	51–19	79
		55–332	97
		55–353	115
		55–375	85
		55–635	133
		55–1030	115
		All	*624*
	2	31–55	97
		40–1011	100
		51–1153	100
		55–351	97
		55–368	115
		55–376	43
		All	*552*
	3	22–1004	115
		55–2043	79
		55–18	100
		All	*294*
	All		1,470

TABLE D-4 (*Continued*)

PROBLEM AREA [a]	PRIORITY [b]	PROJECT CODE NO.	EST. COST ($1,000)
1–5	1	22–2210	115
		81–2200	79
		55–2201	79
		55–2202	133
		55–2206	115
		81–2034	115
		84–547	133
		84–558	85
		84–600	85
		All	*939*
	2	11–1051	85
		22–2004	133
		55–326	79
		55–344	175
		55–401	115
		84–2205	97
		82–6	97
		84–20	115
		84–26	97
		84–545	97
		84–548	61
		84–619	115
		84–2046	115
		90–1150	97
		All	*1,478*
	3	84–21	97
		84–22	97
		84–24	115
		90–1113	97
		All	*406*
	All		2,823
2–1	1	53–380	70
		53–2045	115
		53–2209	97
		All	*282*
	2	22–430	115
		22–447	115
		22–732	133
		27–17	79
		53–379	115
		53–382	85
		All	*642*
	3	22–449	130
		22–1019	145
		24–390	130
		24–411	97
		53–2041	145
		All	*647*
	All		1,571
2–2	1	15–578	97
		53–308	97
		53–360	79
		53–369	97
		54–2210	115
		55–350	79
		54–2205	97
		55–2206	115
		55–2207	97
		All	*873*
	2	15–177	97
		15–579	115
		54–2213	79
		51–386	133
		51–1140	79
		53–320	79
		53–341	43
		53–348	97
		53–352	85
		53–363	115
		53–364	79
		53–365	169
		53–367	145
		53–370	70
		53–424	97
		53–2062	133
		53–2212	115
		54–349	133
		54–361	97
		54–425	79
		54–433	97
		55–321	79
		55–359	97
		All	2,312
	3	15–1123	97
		53–312	61
		53–362	61
		53–2211	97
		54–2073	115
		All	*431*
	All		3,616
2–3	1	22–733	97
		34–1168	97
		40–237	115
		40–277	97
		41–228	61
		53–35	97
		53–331	109
		53–1134	97
		53–2209	97
		53–2212	115
		All	*982*

TABLE D-4 (*Continued*)

PROBLEM AREA [a]	PRIORITY [b]	PROJECT CODE NO.	EST. COST ($1,000)
	2	22–359	97
		22–423	115
		22–730	115
		22–731	97
		22–734	97
		22–735	97
		53–256	97
		53–327	100
		53–379	115
		53–402	97
		53–729	85
		53–1029	115
		90–1169	115
		All	*1,342*
	3	22–726	169
		22–732	133
		53–368	115
		53–373	61
		53–374	145
		53–1014	115
		All	*738*
	All		3,062
2–4	1	40–209	79
		40–252	79
		40–300	61
		41–220	145
		41–221	124
		41–223	124
		41–281	115
		All	*727*
	2	22–1006	169
		27–292	97
		31–235	115
		31–241	100
		40–182	100
		40–217	115
		40–1165	124
		41–243	79
		41–279	115
		41–1038	115
		All	*1,129*
	3	40–204	100
		40–561	115
		40–1002	97
		40–1031	85
		40–1166	115
		All	*512*
	All		2,368
2–5	1	15–578	97
		15–579	115
		51–13	97
		53–356	97
		53–362	61
		53–364	79
		53–385	43
		84–2028	115
		All	*704*
	2	22–318	97
		22–319	61
		22–320	79
		22–424	97
		22–2059	70
		51–232	97
		51–256	97
		52–327	100
		52–330	97
		52–343	97
		52–352	85
		52–404	97
		53–348	97
		53–367	145
		53–373	61
		53–378	97
		53–429	61
		54–357	97
		54–361	97
		54–366	97
		54–2205	97
		54–2206	115
		54–2207	97
		All	*2,135*
	3	22–425	79
		51–390	130
		52–329	79
		52–358	97
		53–360	79
		53–363	115
		53–365	169
		53–402	97
		53–2062	133
		All	*978*
	All		3,817
3–1	1	11–656	97
		82–538	85
		All	*182*
	2	11–258	70
		11–621	97
		13–10	100
		13–605	115
		13–617	61
		13–680	97
		15–622	85
		22–315	79
		22–2004	133
		24–451	97
		24–455	97
		24–665	100
		24–672	85
		24–1035	85
		70–608	79
		All	*1,380*

TABLE D-4 (*Continued*)

PROBLEM AREA [a]	PRIOR-ITY [b]	PROJECT CODE NO.	EST. COST ($1,000)
	3	11–664	115
		11–709	97
		22–1034	115
		22–1006	169
		24–400	109
		24–452	97
		24–607	85
		24–2036	115
		70–616	79
		84–722	100
		All	*1,081*
	All		2,643
3–2	1	22–2042	97
		24–665	100
		24–712	70
		70–700	79
		83–518	70
		All	*416*
	2	22–697	79
		22–1025	79
		22–2029	115
		24–612	61
		24–672	85
		24–709	97
		24–1034	115
		55–321	79
		55–401	115
		82–529	97
		82–623	97
		82–2004	133
		83–4	97
		83–526	97
		83–527	115
		84–2058	97
		All	*1,558*
	3	55–400	109
		81–453	115
		81–2030	97
		82–455	97
		82–535	115
		82–544	115
		All	*648*
	All		2,622
3–3	1	11–714	70
		82–538	85
		83–524	115
		83–526	97
		83–527	115
		83–624	115
		All	*597*
	2	13–680	97
		15–575	85
		15–708	85
		24–455	97
		83–516	85
		83–621	97
		84–546	79
		All	*625*
	3	11–613	115
		24–400	109
		70–685	85
		82–453	115
		82–2004	133
		All	*557*
	All		1,779

[a] See Chapter Five for explanation of problem areas, Appendix B for problem area statements, and Table D-3 for proposed research project statements.
[b] 1 = low; 2 = intermediate, 3 = high.

TABLE D-5

PROPOSED RESEARCH PROJECTS BY COMPOSITE PRIORITY

PRIORITY [a]	PROJECT CODE NO.	PROBLEM AREA	EST. COST ($1,000)
20	22–2004	1–5	133
x20	22–2004	3–1	133
x20	82–2004	3–3	133
x20	82–2004	3–2	133
19	22–425	2–5	79
x19	53–425	1–3	79
x19	54–425	2–2	79
19	54–2205	2–2	97
x19	54–2205	1–3	97
x19	54–2205	2–5	97
x19	55–2205	1–2	97
x19	84–2205	1–5	97
18	24–400	3–3	109
x18	24–400	3–1	109
x18	55–400	3–2	109
15	22–1006	2–4	169
x15	22–1006	3–1	169
15	24–390	2–1	130
15	24–455	3–3	97
x15	24–455	3–1	97
15	40–1166	2–4	115
x15	40–1166	1–2	115
x15	41–1006	1–2	169
x15	51–390	2–5	130
15	82–453	3–2	115
x15	82–453	3–3	115
x15	82–455	3–2	97
13	22–2210	1–5	115
x13	40–561	2–4	115
13	40–561	1–2	115
x13	53–363	2–2	115
13	53–363	2–5	115
x13	53–365	2–2	169
13	53–365	2–5	169
13	53–2062	2–2	133
x13	53–2062	2–5	133
13	54–2206	2–5	115
x13	54–2210	2–2	115
x13	54–2210	1–3	115
x13	54–2210	1–2	115
x13	55–2206	2–2	115
x13	55–2206	1–5	115
x12	22–359	2–3	97
12	22–359	1–3	97
12	55–359	2–2	97
x12	55–401	1–5	115
12	55–401	3–2	115
11	53–360	2–2	79
x11	53–360	2–5	79
11	53–402	2–3	97
x11	53–402	2–5	97
10	15–431	1–3	100
10	22–320	2–5	79
10	22–424	2–5	97
10	22–430	2–1	115
x10	22–430	1–3	115
10	27–292	2–4	97
x10	27–292	1–2	97
x10	27–431	1–2	100
10	41–279	2–4	115
x10	41–279	1–2	115
10	52–352	2–5	85
x10	53–320	2–2	79
x10	53–348	2–2	97
10	53–348	2–5	97
x10	53–352	2–2	85
10	53–367	2–2	145
x10	53–367	2–5	145
x10	53–424	2–2	97
10	54–361	2–2	97
x10	54–361	2–5	97
10	54–2207	2–5	97
10	55–321	2–2	79
x10	55–321	3–2	79
x10	55–2207	2–2	97
09	11–709	3–1	97
09	15–583	1–3	97
09	15–2097	1–3	97
09	22–1034	3–1	115
09	22–2042	1–3	97
x09	22–2042	3–2	97
x09	24–709	3–2	97
x09	24–1034	3–2	115
09	40–204	2–4	100
09	40–1002	2–4	97
09	40–1031	2–4	85
09	52–329	2–5	79
09	52–346	1–3	79
09	52–358	2–5	97
09	53–362	2–2	61
x09	53–362	2–5	61
09	53–373	2–3	61
x09	53–373	2–5	61
09	81–2030	3–2	97
09	82–535	3–2	115
09	82–544	3–2	115
09	84–21	1–5	97
09	84–22	1–5	97
09	84–24	1–5	115
09	90–1113	1–5	97
08	22–315	3–1	79
x08	22–315	1–3	79
08	24–672	3–1	85
x08	24–672	3–2	85
x08	51–256	2–5	97
08	52–327	2–5	100
x08	53–256	2–3	97
x08	53–327	2–3	100
08	83–526	3–3	97
x08	83–526	3–2	97
08	83–527	3–3	115
x08	83–527	3–2	115
07	15–579	2–2	115
x07	15–579	2–5	115
07	22–732	2–1	133
x07	22–732	2–3	133
07	40–300	2–4	61
x07	40–300	1–2	61
07	53–364	2–2	79
x07	53–364	2–5	79
06	11–613	3–3	115
06	11–621	3–1	97
06	11–1051	1–5	85
06	13–680	3–3	97
x06	13–680	3–1	97
06	15–649	1–3	97
06	15–1123	2–2	97
06	22–318	2–5	97
06	22–319	2–5	61
06	22–410	1–3	61
06	22–422	1–3	85
06	22–449	2–1	130
06	22–697	3–2	79
06	22–1019	2–1	145
06	22–1025	3–2	79
06	22–2029	3–2	115
06	22–2059	2–5	70
06	24–411	2–1	97
06	24–451	3–1	97
06	24–612	3–2	61
06	31–235	2–4	115
06	31–241	2–4	100
06	40–182	2–4	100
06	40–217	2–4	115
06	40–387	1–2	115
06	40–1165	2–4	124
06	41–243	2–4	79
x06	41–451	1–2	97
06	41–1038	2–4	115
06	51–232	2–5	97
06	51–388	1–2	61
06	52–330	2–5	97
06	52–343	2–5	97
06	52–404	2–5	97
06	53–312	2–2	61
06	53–378	2–5	97
06	53–379	2–1	115
x06	53–379	2–3	115
06	53–409	1–2	115
06	53–428	1–3	115
06	53–429	2–5	61
06	53–432	1–3	85
06	53–435	1–3	97
06	53–436	1–3	97
06	53–2041	2–1	145
06	53–2209	2–1	97
x06	53–2209	2–3	97
x06	53–2209	1–3	97
06	53–2211	2–2	97
06	54–357	2–5	97
06	54–366	2–5	97
06	54–2073	2–2	115
06	55–326	1–5	79
06	55–344	1–5	175
06	55–570	1–3	115
06	55–2201	1–5	79
x06	55–2201	1–3	79
06	64–1109	1–2	97
06	70–685	3–3	85
06	82–6	1–5	97
06	82–529	3–2	97
06	82–623	3–2	97
06	83–4	3–2	97
x06	83–621	3–3	97
06	83–713	1–3	61
06	84–20	1–5	115
06	84–26	1–5	97
06	84–545	1–5	97
06	84–548	1–5	61
06	84–619	1–5	115
06	84–2046	1–5	115
06	84–2058	3–2	97
06	90–1150	1–5	97
05	15–578	2–2	97
x05	15–578	2–5	97
05	24–665	3–1	100
x05	24–665	3–2	100
05	53–368	2–3	115

TABLE D-5 (*Continued*)

PRIORITY [a]	PROJECT CODE NO.	PROBLEM AREA	EST. COST ($1,000)	PRIORITY [a]	PROJECT CODE NO.	PROBLEM AREA	EST. COST ($1,000)	PRIORITY [a]	PROJECT CODE NO.	PROBLEM AREA	EST. COST ($1,000)
05	53–2212	2–2	115	03	41–281	2–4	115	02	40–1011	1–4	100
x05	53–2212	2–3	115	03	51–13	2–5	97	02	51–1153	1–4	100
x05	55–368	1–4	115	03	52–2043	1–4	79	02	53–308	2–2	97
05	55–376	1–4	43	03	53–356	2–5	97	02	53–369	2–2	97
x05	55–376	1–3	43	03	53–374	2–3	145	02	53–380	2–1	70
04	15–575	3–3	85	03	53–385	2–5	43	02	53–729	2–3	85
04	15–577	2–2	97	03	53–439	1–3	79	02	53–1029	2–3	115
04	15–708	3–3	85	03	53–1014	2–3	115	02	53–2045	2–1	115
04	22–447	2–1	115	03	55–18	1–4	100	02	55–350	2–2	79
04	27–17	2–1	79	03	55–2202	1–5	133	02	55–351	1–4	97
04	40–304	1–2	79	03	70–616	3–1	79	02	61–33	1–1	97
04	51–386	2–2	133	03	70–700	3–2	79	02	61–72	1–1	97
04	51–1140	2–2	79	03	81–2034	1–5	115	02	61–153	1–1	79
04	51–1162	1–2	97	03	81–2200	1–5	79	02	62–97	1–1	61
04	53–341	2–2	43	03	82–538	3–3	85	02	62–99	1–1	85
04	53–370	2–2	70	x03	82–538	3–1	85	02	62–100	1–1	97
04	53–382	2–1	85	03	83–518	3–2	70	02	70–608	3–1	79
04	54–349	2–2	133	03	84–547	1–5	133	02	83–524	3–3	115
04	54–433	2–2	97	03	84–558	1–5	85	02	83–624	3–3	115
04	54–2213	2–2	79	03	84–600	1–5	85	02	90–1169	2–3	115
04	55–353	1–3	115	03	84–722	3–1	100	01	11–656	3–1	97
x04	55–353	1–4	115	03	84–2028	2–5	115	01	22–733	2–3	97
04	83–516	3–3	85	02	11–258	3–1	70	01	31–253	1–1	79
04	84–546	3–3	79	02	11–714	3–3	70	01	34–1168	2–3	97
03	11–664	3–1	115	02	13–10	3–1	100	01	40–207	1–1	115
03	22–408	1–3	97	02	13–605	3–1	115	01	40–237	2–3	115
03	22–434	1–3	115	02	13–617	3–1	61	01	40–267	1–1	169
03	22–726	2–3	169	02	15–622	3–1	85	01	40–277	2–3	97
03	22–1004	1–4	115	02	22–423	2–3	115	01	41–29	1–1	97
03	24–452	3–1	97	02	22–730	2–3	115	01	41–30	1–1	97
03	24–607	3–1	85	02	22–731	2–3	97	01	41–228	2–3	61
03	24–712	3–2	70	02	22–734	2–3	97	01	41–255	1–1	145
03	24–2036	3–1	115	02	22–735	2–3	97	01	51–19	1–4	79
03	26–463	1–1	133	02	23–91	1–1	70	01	53–35	2–3	97
03	32–254	1–1	97	02	23–440	1–2	70	01	53–331	2–3	109
03	34–1009	1–1	97	02	24–1035	3–1	85	01	53–1134	2–3	97
03	40–209	2–4	79	02	25–112	1–1	79	01	55–332	1–4	97
03	40–252	2–4	79	02	25–114	1–1	79	01	55–375	1–4	85
03	41–183	1–1	97	02	25–115	1–1	97	01	55–635	1–4	133
03	41–220	2–4	145	02	26–69	1–1	97	01	55–1030	1–4	115
03	41–221	2–4	124	02	31–55	1–4	97	01	64–107	1–1	79
03	41–223	2–4	124	02	33–1107	1–1	70	01	64–109	1–1	79
03	41–230	1–1	97	02	34–76	1–1	97				

[a] Proposed project appears more than once when project is in more than one problem area. Repeated projects are marked "x"

APPENDIX E

SURVEY FORMS

Bertram D Tallamy Associates · Wilbur Smith and Associates
Research Needs in Highway Transportation
NCHRP Project 20-2

Literature Digest

File No. TL-12

Classifications.
11100
11200
11400

Disposition: Filed in PUBLICATION drawer under TL-12

Publication 89th Congress, 2nd Session – House Report No. 1664
Volume ______ No. ______ Page/s 42 Date June 27, 1966
Title Federal Research and Development Program; The Decisionmaking Process
Author ______

ABSTRACT

I. The Federal decision-making process with respect to its $16 Billion R. and D. program deeply affects how fast the Federal Government can move toward important national goals, how the Nation's private sector R. and D. is allocated, and how the Nation's supply of scientific manpower is employed.
II. Three examples of aggressive Federal R. and D decisionmaking ··· the defense, space, atomic energy programs.
III. Three examples of less aggressive Federal R. and D. decisionmaking ··· the urban transportation, housing and hospital facilities, and water pollution control programs.

SUMMARY COMMENTS

A basic document that can be quoted in our report as an authority. Will be of some help in structuring and in noticing the deficiencies of the Highway Research Program

Reviewed by: J. H. K. Date: Sept. 19, 1966

Figure E-1. Literature digest form.

Bertram D. Tallamy Associates - Wilbur Smith and Associates
Research Needs in Highway Transportation
NCHRP Contract HR 20-2
T/A 107-3

INTERVIEW REPORT FORM

File No. 21-26

Classifications: 22/190

Disposition: Project file

Agency — — — Foundation

Persons Interviewed: — — — —; — — — —; — — — —

Title: Director, Engineering Division; " Safety Division; Traffic Engineering Division

Summary of Comments

1. Structure Structuring of hwy transportation research needs requires consideration of methodology of hwy. programming procedures, and coordination of urban with rural, and physical with basic research It needs an economic approach to determine the highway segment of transportation and the system segments of the highway component.

2. Objectives Improve knowledge of transportation facts so public agencies can provide better satisfactions to their patrons.

3. Priorities & Costs Logically these should be based on benefits exceeding costs but socio-economic considerations may indicate modifications to fit political or policy objectives.

4. Research Implementation Brief summary bulletins issued and circulated to organizational levels where application of findings is most likely to take place.

Date: Sept. 12, 1966

Interviewer: C J. H.

Figure E-2. Interview report form.

Bertram D. Tallamy Associates - Wilbur Smith and Associates
Research Needs in Highway Transportation
NCHRP Contract HR 20-2
T/A 207-3

RESEARCH PROJECT REPORT FORM

File No. SP-4

Classifications: 12622
12682
12322
.12382

Disposition: Summarize and include in problem statement tabulation.

Agency: — — — State Highway Department

Persons Interviewed: — — — — — —

Title: Chief Highway Commissioner

Project Title: Practical Design Aids for Urban Highway Facilities

Project Statement: The AASHO basic system for design is adequate for producing sound facilities and structures. The states need much more guidance on such matters as when to depress or elevate; how to relate freeways to parking facilities; how to coordinate with public transportation facilities, in highways or otherwise; air rights; vehicular-pedestrian separations; road plans related to urban renewal program, etc

Research Objectives: To design and plan facilities which answer many of the new questions and problems being raised about urban transportation program.

Date: August 17, 1966

Interviewer: N. S. S.

Figure E-3. Research project report form.

APPENDIX F

BIBLIOGRAPHY

ALBERTSON, M. L., ET AL., "National Requirements of Civil Engineering Research." (draft).

ALBERTSON, M. L., and TAYLOR, D., "Study of Research Needs and Requirements in Civil Engineering." ASCE and Univ. of Colorado (outline).

"Alternative Regional Plans Presented to Counties." Southeastern Wisconsin Regional Planning Commission *Newsletter*, Vol. 6, No. 3 (May-June 1966).

Annual Report 18, Fiscal Year 1966. Virginia Highway Research Council (July 21, 1966).

"Application of Highway Research Findings." *HRB Special Report 55* (1960).

Army Regulations 1-1 and The New Family of Army Plans, pp. 10-11 (Feb. 11, 1966).

ASCE Research Conference. Prepared by the Committee on Research, p. 91 (Jan. 1963).

BAKER, R. F., "National Trends in Highway Research." *Proc. 15th California Street and Highway Conf.*, pp. 167-171 (1963).

BAKER, R. F., "The Present and Future of Engineering in Highway Transportation." Ann. Meeting of Amer. Soc. for Engineering Education (June 23, 1966).

BAKER, R. F., "Research Advisory Committees or Councils." U. S. Bur. of Public Roads circular memorandum (Sept. 1, 1963).

BAKER, R. F., "Research Payoff." Address given at 21st Ann. Conv., National Limestone Inst.

BAKER, R. F., "What Makes Research Tick?" *Amer. Road Builder*, Vol. 43, No. 5, pp. 14-15 (May 1966).

BAUER, A. M., *Simultaneous Excavation and Rehabilitation of Sand and Gravel Sites.* Research project report of Univ. of Illinois for National Sand and Gravel Association (1965).

BEER, C. G., Urban Planning Department, Concerning ASCE Statement of Research Needs. Memorandum from Dept. of Public Works, Calif. (July 13, 1966).

"Bituminous Materials and Mixes, Construction, General Materials, Foundations (Soils)." *HRB Circ. No. 30* (Sept. 1966).

BOOZ-ALLEN APPLIED RESEARCH, *Analysis of the Function of Transportation—A Conceptual Framework.* Vol. 1, No. 1 (June 1966).

CAMPBELL, M. E., "Guide for Shaping a Comprehensive Highway Research Program." p. 18.

CAMPBELL, M. E., "Our Highway Heritage Abroad." p. 16 (July 14, 1966).

CAMPBELL, M. E., "Random Conversations—Some Suggestions for HRB Staff." p. 13 (Apr. 21, 1965).

CAMPBELL, M. E., "Research Purpose and PPPSS (Policies, Processes, Procedures, Standards, Specifications)." p. 3 (July 21, 1964).

CAMPBELL, M. E., "Toward a Strategy of Highway Research Administration." p. 18 (Apr. 29, 1966).

CAMPBELL, M. E., "What Is a Highway roblem?" p. 10.

CAMPBELL, M. E., and NEWCOMB, R., "The Challenge of Highway Technology in Developing Countries." *HRB Record No. 125*, pp. 20-29 (1966).

Chicago Area Transportation Study, Vol. III, pp. 6-20 (Apr. 1962).

"The City and the Car." Compiled from the remarks of Henry Ford II at a meeting of the Young Men's Business Club (July 21, 1966).

"Conference on the Application of Engineering Technology to the Problems of Appalachia Transportation." Prepared by West Virginia University, Vol. 2, p. 95.

"Conference on Transportation Research." Nat. Acad. of Sciences Publ. No. 840 (Aug. 1960).

"Continuing Engineering Studies." Prepared by The Joint Advisory Committee, p. 112 (1965).

"Coordination of Research and Development by The Office of Research and Development (BPR, R&D)." (July 30, 1965).

"Current Trends in the Application of the Doctrine of Sovereign Immunity to Highway Construction and Management." HRB Problem Area Statements, p. 965.

CURTISS, C. D., "Methods of Advancing Needed Highway Research—Including Establishment of a Priority List." *Proc. Ninth Pan American Highway Congress*, Vol. 2, p. 515-29 (May 6-18, 1966).

DAVIS, H. E., "Notes and Comments on a Proposed National Transportation Study." Paper for Discussion U & D Surveys L & RB Meeting, p. 10 (Jan. 8, 1962).

"Defining Requirements of Overtaking and Passing Maneuvers." Prepared by Traffic Systems Division, U. S. Bur. of Public Roads (Dec. 18, 1964).

"Division of Engineering Grants FY64 and FY65." *National Science Foundation Grants.*

Engineering Foundation Research Conference on Urban Transportation Research. (Aug. 26-30, 1963).

"Engineered Safety Through Research and Development." U. S. Bur. of Public Roads (May 5, 1965).

"An Expanded National Highway Research Program." *Traffic Quart.* (July 1963).

"Exploration-Classification (Soils), Foundations (Soils), Mechanics (Earth Mass), Soil Science, Construction, General Materials, Photogrammetry, Highway Design, Pavement Design, Bridge Design." *HRB Circ. No. 37* (Aug. 1966).

"The Federal Research and Development Budget FY57, 58, 59." *NSF 58-30.*

"The Federal Research and Development Program: The Decision-Making Process." Hearings before a Subcommittee of the Committee on Government Operations, House of Representatives, 89th Congress, p. 212 (Jan. 7, 10, 11, 1966).

"Federal Research and Development Program: the Decision-Making Process." House Report, November 1964 (89th Congress, 2nd Session), p. 42 (June 27, 1966).

"4,000,000 by 2000! Preliminary Proposals for Guiding Change." The Joint Program, St. Paul, Minn., Report No. 2 (Dec. 1964).

"Funds for Research and Development in Industry." *NSF 62-3.*

"Funds for Scientific Activities in the Federal Government FY53 and 54." *NSF 58-14.*

"Future Researches." Memorandum to the Joint National Sand and Gravel Assn.-National Ready Mix Concrete Assn., Engineering and Research Committee (Feb. 5, 1966).

"Goals for the Development of the Twin Cities Metropolitan Area." The Joint Program, St. Paul, Minn., Report No. 3 (Nov. 1965).

GOLDSTEIN, S., "Considerations in a Long-Range Program of Economic and Social Research for Highway Transport." U.S. Bur. of Public Roads (Aug. 7, 1963).

HANSON, W. B., and HARTLEY, D. K., "Proposal for a Program of AIP Involvement in Planning Research." Memorandom to Board of Governors, Amer. Inst. of Planners (Aug. 1964).

HANSON, W. B., and HARTLEY, D. K., "Regional Planning Research: The Role of the Federal and State Government." Amer. Inst. of Planners Report on 1965 Government Relations and Planning-Policy Conference: Emerging Regional Cities of America, p. 109-28 (1965).

HARTLEY, D. K., and HOUSEN, D. K., "Proposal for a Program of AIP Involvement in Planning Research." Memorandum to Board of Governors, Amer. Inst. of Planners, p. 11 (Aug. 1964).

"Highway Progress 1965." Prepared by U. S. Bureau of Public Roads, p. 115, (Oct. 1965).

"Highway Research and Development Studies." Prepared by U. S. Bureau of Public Roads, Vol. 1964, p. 177 (Mar. 1964); Vol. 1965, p. 158 (May 1965).

"Highway Research Board's Correlation Service and NCHR Program." Prepared by AASHO Executive Committee (June 20, 1966).

"Highway Research in the United States: Needs, Expenditures and Applications 1959." *HRB Spec. Rep. 55* (1960).

"Highway Research in Progress." HRB (Sept. 1965).

"Highway Research Projects Using Federal-Aid Research and Planning Funds." U. S. Bur. of Public Roads, pp. 1-137 (Sept. 1962).

Highway Research Review, No. 4 (Nov. 1955).

Highway Research Review, prepared by HRB, p. 389 (Jan. 1962).

"Highways and Urban Development—Report on the Second National Conference, Williamsburg, Va." (Dec. 1965).

"Highway Safety." *HRB Circ. No. 45* (Sept. 1966).

HOWARD, J. T., "Community Growth—Impact of the Federal Highway Program." Paper presented at 63rd National Conf. on Government, National Municipal League, Cleveland, Ohio. (Nov. 20, 1957).

HOWARD, J. T., "The Dynamics of Urban Change." Paper presented at MIT Conf. on Transportation and Urban Growth in New England (Dec. 1, 1964).

"Human Capability Research." A Program of Scientific Research in Transportation, prepared by U. S. Bureau of Public Roads, pp. 134-137.

"An Interim Report Covering a 17-Country Inventory—World Survey of Current Research and Development on Roads and Road Transport." Prepared for U. S. Bur. of Public Roads by International Road Federation, Washington, D. C. (revised July 15, 1966).

JOHNSON, C., "Practical Operating Procedures for Progressive Rehabilitation of Sand and Gravel Sites." Research project report, Univ. of Illinois for National Sand and Gravel Assn. (1966).

KARGER, D. W., and MURDICK, R. G., *Managing Engineering and Research.* Industrial Press, New York (1965).

LEVIN, D., "HRB: First Progress Report on Ad Hoc Committee on New Subject Matter." Report of Dept. of Economics, Finance and Administration (HRB). (July 18, 1966).

Major Transportation Policy Research Needs. Transportation Assn. of America, pp. 1-12 (Dec. 1965).

MARTIN, J. L. Letter, National Assn. of Counties to U. S. Bur. of Public Roads (Sept. 28, 1966).

Memoranda. Prepared by the HRB (Oct. 1966).

MICHAELS, R. M., "Traffic Safety: A Challenge to Systems Engineering." U. S. Bur. of Public Roads (Mar. 3, 1965).

MICKLE, D. G., "The Anatomy of Highway Progress." Address presented at 3rd Biennial Conf., Australian Road Research Board, Sidney, Australia (Sept. 5-9, 1966).

MICKLE, D. G., "The National Cooperative Highway Research Program." *Traffic Quart.,* Vol. 20, No. 4, pp. 483-501. (Oct. 1966).

MILLER, C. L., "Contribution to the Annual Report of the School of Engineering, MIT, for the Academic Year 1965/66." (Sept. 15, 1966).

MILLER, C. L., "A Research Approach to the Engineering of Future Transportation Systems." Address presented at Transportation and Urban Growth—A Special Conference for New England Executives, MIT (Dec. 1, 1964).

MORONY, L., "Research Frontiers in Motor Vehicles and Traffic Laws." HRB Problem Area Statements, pp. 954-961 (Aug. 19, 1964).

NATESS, C. B., "A Study to Examine the Interaction Between the Physical Aspects of Urban Form and Specialized Services." HRB Problem Statements, pp. 72-77 (Mar. 18, 1965).

"National Association of Counties (NACO)—a Platform on Transportation." (July 1966).

"A National Program of R & D for Highway Transportation." Circular memorandum prepared by U. S. Bur. of Public Roads, pp. 31 (Sept. 20, 1965).

"A National Program of Research and Development for Highway Transportation." pp. 1-32 (July 19, 1966).

National Science Foundation 56-12.

"National Travel—Passenger Transportation Survey—1963 Summary." *1963 Census of Transportation.* U. S. Bureau of the Census (1964).

NELSON, R. R., "The Economics of Parallel R & D Efforts: P Sequential-Decision Analysis." U. S. Air Force Project, Rand Research Memorandum, p. 40 (Nov. 12, 1959).

"New Horizons for Highway Safety Through Driving Simulation." National Conf. on Highway Simulation (Feb. 27-Mar. 1, 1961).

"North Dakota State Highway Department Planning and Research 1966 Work Program—HPR-1(2)." North Dakota State Highway Dept. (Nov. 1, 1966).

"Notes on Conference Relating to Preparation of Comprehensive and Coordinated Plan for Highway Transportation Research." HRB Problem Area Statements, prepared by Legal Studies Department of HRB, pp. 933-35 (June 23, 1965).

"Objectives of New Department of Transportation Outlined by President Johnson." National Highway Users Conf. Information Service (Oct. 20, 1966).

"Outline of the Continuing Work of the Nebraska Program and Planning Section for the Period from January 1, 1963, to December 31, 1963." (Also ". . . Jan. 1, 1962-Dec. 31, 1962.")

OWEN, W., "Road Transportation and Food Production." *HRB Record No. 25,* pp. 1-9 (1966).

"Personnel Structure for Coordination of Joint Support of Studies by Several States and/or BPR." (Feb. 17, 1966).

"Priority Problems in Urban Transportation Research." *HRB Circ. No. 483* (Oct. 1962).

"Proceedings of a Conference on Research and Development and Its Impact on the Economy." Prepared by National Science Foundation, Govt. Printing Off., Washington, D.C., p. 223 (1958).

"Program and Planning Section Work Program Outline for Projects HPR
1 (2)—January 1, 1964, to December 31, 1964
1 (3)—January 1, 1965, to December 31, 1965
1 (4)—January 1, 1966, to December 31, 1966." State of Nebraska, Dept. of Roads.

"Program Notes." Vol. 1, No. 1-6. The Joint Program, St. Paul, Minn., (Mar. 1964-Sept. 1966).

"A Program of Behavioral Research for Highway Transport." (July 30, 1962).

"A Program of Scientific Research in Transportation." Prepared by U. S. Bur. of Public Roads, Office of Research and Development, p. 50 (Dec. 1965).

"A Projection of Technology Applicable to Future Highway System of the Boston-Washington Corridor." Cornell Aeronautical Laboratory report for U. S. Department of Commerce, Undersecretary for Transportation Policy, Vol. 1, p. 376 (Oct. 2, 1964).

"Proposal for Authorization of Initial Research Studies."

"Prospectus for Cooperative Research." Prepared by Amer. Public Works Assn. Research Foundation (July 1966).

"Rehabilitation of Worked-Out Sand and Gravel Deposits." National Sand and Gravel Assn. pamphlet (May 1, 1961)

"Report of Task Group to Define Proposed Transportation Research and Development Program." Prepared by U. S. Bur. of Public Roads (Feb. 4, 1966).

"A Report on the Interagency Liaison Conference for Highway Safety." Edited by U. S. Bur. of Public Roads, p. 19 (Feb. 1966).

"Report on Research Needs: Soils, Geology, and Foundations." *HRB Circ. No. 37.*

"Report of the Special Ad Hoc Committee on HRB Correlation Service and the National Cooperative Highway Research Program." (June 20, 1966).

"Research Areas Suggested for Emphasis within the NCHRP." Prepared by AASHO, p. 2.

"Research and Development in the Aircraft and Missile Industry (1956-61)." *NSF 63-19.*

"Research—A Section of the *Action Program* for Highway Safety." A report of the President's Committee for Traffic Safety (1963).

Research Digest. Bureau of Community Planning, Univ. of Illinois, Vol. 13, No. 1 (Spring and Summer, 1966).

"Research into Social Behavior Relative to Transportation." A Program of Scientific Research in Transportation, prepared by U. S. Bur. of Public Roads, pp. 89-94.

"Research Needs for Highway Transportation." Prepared by Committee on Research, Highway Division, ASCE, p. 12 (June 1, 1966).

"Research Projects of the Bureau of Public Roads." (Feb. 1961).

ROBERTS, E. B., *The Dynamics of Research and Development.* Harper and Row, p. 352 (1964).

ROBERTS, T. H., "Transportation and Metropolitan Development." Amer. Inst. of Planners report on the Government Relations and Planning-Policy Conference: Emerging Regional Cities of America, pp. 31-43. (1965).

ROGERS, C. F. Mimeographed publication, p. 11 (Jan. 1965).

ROGIER, D. A., and SCHELLE, K. L., "Site Utilization and Rehabilitation Practices for Sand and Gravel Operations." Prepared by Schelle Associates for National Sand and Gravel Assn. (1964).

"The Role of Public Hearings in the Highway Program." HRB Problem Area Statements, pp. 962-64.

RUBIN, I., "Comparison of Changes Between Trip Generation Rates from 1953 and 1965." p. 28.

"Safety Research." A Program of Scientific Research in Transportation, prepared by U. S. Bur. of Public Roads, pp. 138-141.

SEILER, R. E., *Improving the Effectiveness of Research and Development.* McGraw-Hill (1965).

"Social Impact: Environmental Quality, Community Effects, and Highway Transportation." Prepared by U. S. Bur. of Public Roads (June 28, 1966).

"Some Notes on Community Values and Their Effects on Public Policies on Transportation and Development." HRB Problem Area Statements, pp. 47-8 (Mar. 15, 1965).

"Sources of Information in Transportation." Transportation Center, Northwestern Univ., p. 262 (1964).

SWAIN, R., and GRANVILLE, W., "Inventorying Research and Development on Roads and Road Transport." *Hwy. Res. Record No. 125,* pp. 11-19 (1966).

"Task and Study Statements of the National Program of the R & D for Highway Transportation." Circular memorandum prepared by U. S. Bur. of Public Roads (Aug. 5, Sept. 13, 1966).

"Traffic Control and Operation of Highway Design." *HRB Circ. No. 39.*

"Traffic Flow." *HRB Circ. No. 24* (June 1966).

"Traffic Measurements." *HRB Circ. No. 31* (July 1966).

Transit Fact Book. American Transit Assn. (1966).

"Transportation Research." Prepared by Transportation Assn. of America, pp. 1-52 (Dec. 1964).

"Truck Inventory and Use Survey—Middle Atlantic Division." *1963 Census of Transportation,* U. S. Bureau of the Census (1965).

"Truck Inventory and Use Survey—U. S. Summary." *1963 Census of Transportation,* U. S. Bureau of the Census (1965).

UKRF Annual Report (1965).

"University Transportation and Accident Prevention Centers." A study conducted by Traffic Safety Research and Education Committee, Assn. of State Universities and Land-Grant Colleges with assistance of National Commission on Safety Education, National Education Assn. (Apr. 1962).

"Urban Transportation Issues and Trends." Prepared by Highway Economics Research Committee, American Maintenance Assn. (June 1963).

" 'What's this big Joint Program I've been hearing about?' asked T. C. Mits . . ." A pamphlet prepared by the Joint Program, St. Paul, Minn.

WHITTON, R. M., Letter to Sen. Abraham Ribicoff (May 5, 1965).

WHITTON, R. M., "Research in Highway Safety for the Next Decade by the Bureau of Public Roads." (May 27, 1965).

WILLIAMS, H. A., Address presented at Fifth World Meeting, International Road Federation, London (Sept. 20, 1966).

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7	Comparison of Different Methods of Measuring Pavement Condition—Interim Report (Proj. 1-2), 29 p., $1.80
8	Synthetic Aggregates for Highway Construction (Proj. 4-4), 13 p., $1.00
9	Traffic Surveillance and Means of Communicating with Drivers—Interim Report (Proj. 3-2), 28 p., $1.60
10	Theoretical Analysis of Structural Behavior of Road Test Flexible Pavements (Proj. 1-4), 31 p., $2.80
11	Effect of Control Devices on Traffic Operations—Interim Report (Proj. 3-6), 107 p., $5.80
12	Identification of Aggregates Causing Poor Concrete Performance When Frozen—Interim Report (Proj. 4-3(1)), 47 p., $3.00
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15	Identification of Concrete Aggregates Exhibiting Frost Susceptibility—Interim Report (Proj. 4-3(2)), 66 p., $4.00
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17	Development of Guidelines for Practical and Realistic Construction Specifications (Proj. 10-1,) 109 p., $6.00
18	Community Consequences of Highway Improvement (Proj. 2-2), 37 p., $2.80
19	Economical and Effective Deicing Agents for Use on Highway Structures (Proj. 6-1), 19 p., $1.20
20	Economic Study of Roadway Lighting (Proj. 5-4), 77 p., $3.20
21	Detecting Variations in Load-Carrying Capacity of Flexible Pavements (Proj. 1-5), 30 p., $1.40
22	Factors Influencing Flexible Pavement Performance (Proj. 1-3(2)), 69 p., $2.60
23	Methods for Reducing Corrosion of Reinforcing Steel (Proj. 6-4), 22 p., $1.40
24	Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants (Proj. 7-1), 116 p., $5.20
25	Potential Uses of Sonic and Ultrasonic Devices in Highway Construction (Proj. 10-7), 48 p., $2.00
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