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SPECIAL REPORT 99

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SPECIAL REPORT 99

**Organization
of
Highway Research
Summary and Cases**

KENNETH E. COOK
Highway Research Board Staff

Subject Area

11 Transportation Administration

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Preface

In 1952 the Highway Research Board published an analysis of the research organizations in state highway departments. Since then state highway research programs and departmental organizations for research have undergone substantial change. An ad hoc committee on Highway Research Policy and Administration was created by the Highway Research Board in 1965 to review the changes that had occurred in the preceding 15 years. The committee developed a questionnaire that was sent to the states and the findings were published in 1966. However, it was believed that there was a need for greater in-depth analysis of research programs and organizations. So, the staff of the Board visited 13 states to develop case studies. These states were selected to reflect representative types of organizations as well as concentration of research activities. States with large and small programs were included. Of the 50 states, approximately 10 account for more than half of the total expenditure for state highway research; at the opposite end, some 20 states conduct comparatively little research.

This special report begins with an article on considerations and guidelines for research management in developing a research program. The next section summarizes some general patterns illustrated in the case studies. The final section presents detailed case studies for the 13 states and 2 research institutes visited by the staff.

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Considerations and Guidelines for Research Management

KENNETH E. COOK, Highway Research Board

One of the first problems in discussing research management is the definition of "research." Much argument has gone into attempts to define and classify the term. For those who are involved in research, it belongs to the emotionally charged work category. Along with such words as "freedom," "equality," and "justice," the definition of the term is dependent on its environment and the psychological needs of those attempting to define it.

To administrators, research may be defined as obtaining answers to pressing problems for which they do not have solutions. They may make little distinction as to whether the information desired has already been set forth elsewhere and only needs to be retrieved or the problem is one for which there is no existing knowledge. The academician, on the other hand, educationally oriented, and with limited funds and equipment, may define research as the quest for new knowledge.

Many names are given to these different types of research. Perhaps the most liberal definition is that research is the discovery of some fact or truth heretofore unknown to the researcher. With such a definition, the classifications of research can then be dependent on the goals to be achieved through the research program.

Why Do We Need Research?

To anyone considering the institution of a research program or an evaluation of ongoing programs, the first question to answer is, "Why do we need research?" Too often we are prone to start off with the composition of the research program without first clearly understanding why we need research in the first place. What objectives can be obtained through research? Do we want to maximize our gain or minimize our loss? Perhaps we want to achieve an objective that we cannot now accomplish.

If the ultimate purpose of research is to obtain new knowledge, there must be a pre-existing need or desire for such knowledge. To satisfy this need means to bring about change. What is the existing or potential crisis that necessitates the new knowledge that will bring about such change? Is the purpose to satisfy physical, social, economic or psychological needs of the individual or society? Is the need to satisfy the researcher himself or management?

What Are the Different Attitudes Toward Research?

It is necessary to understand the motivations and attitudes of the public, management, and researchers toward any research program. While the effects may be similar, the motives of management and of the researcher may

This article is a revision of a paper that originally appeared in Highway Research News, No. 30, Winter 1968.

be substantially different, and both may be considerably different from society's objectives. For example, in a highway safety program, the researcher's motive, although it is directed toward public service, serves the individual to advance in his own career. Management's objective may be directed at placating public criticism and preventing further restrictive legislation and administrative requirements. The public attitude may be one of general concern and a desire to have a solution to the problem as long as it does not inhibit freedom or cost too much.

In an industrial situation, management may feel a need for research, knowing that without it the firm will lose its competitive position in the market. To management, research means profit or loss in the future. To the researcher, a project may be an outlet for the individual's creative energies, and his efforts are not so much concerned with making profits for the company but rather with satisfying his own sense of accomplishment. Thus, before one can evaluate a research program or even clearly establish the goals, it is necessary to understand the people and environment in which the research program will operate. Behind the clearly articulated goals of a research program there are a multitude of inarticulated emotional needs that are its ultimate purpose. A research program that frustrates the needs of the public, the administrator, or the researcher will be self-defeating.

What Are the Goals of Research?

In a systems approach to research management, the first step is to identify the goals of the program. Once these goals are established they must be subdivided into specific programs and activities. A staff and organization structure must be created along with funding and planning processes. Coordinating and communication networks must be developed as well as operating and feedback systems.

As part of setting goals, available resources must be allocated. Management must decide how much of the research program will be for the development of theoretical research compared with development of new technological advancements and problem solving. The developmental stage in research is expensive and often requires tremendous time, money, and manpower to translate an idea into a working process. How much of the research program efforts should be directed toward this area? Similarly, how much of the research efforts should be directed toward improving existing processes and products? In developing the goals of research, consideration must be taken of the balance between research and available resources. In investing funds for research, the sponsor should evaluate his own expectations as to his desired return on investment and the time period in which he should see such a return.

The concentration of efforts must also be considered. Should the organization concentrate its efforts on a few specialized areas in which there is high probability of success or for which it has already a technical competence, or should it devote its efforts to new areas of research?

There are often ancillary goals to research. At universities, research is generally viewed as a support activity to the instructional program. For the contracting or sponsoring agency, what are the attitudes toward such secondary goals? The goals of research, as noted previously, not only are different within an agency, but may also be substantially different between the agency sponsoring the research and those performing it. Are these goals compatible, and if not, what alternatives are available? How much competition should there be among research agencies, and how much duplication of effort both within the organization and among like organizations? The research program,

if successful, will precipitate change. What resistance to change can be anticipated and how can it be overcome?

How Do You Develop a Research Program?

Once the questions regarding goals have been resolved, the next step is to interpret them into specific research programs. Some of the questions that must be resolved in this area are: What effect will management's endorsement or lack of interest have on the research program? Management's interest is particularly necessary for theoretical or basic research. Management must be willing to accept high cost with little immediate payoff. Theoretical research is out of the mainstream of the organization's activities and frequently the researchers feel isolated from the rest of the operations. In order to keep the program funded and staffed, management must take as direct an interest in research activities as in other long-range planning activities. Highly qualified researchers will only stay in an organization that does not merely tolerate them but that endorses their research. On the other hand, problem-solving research can be more closely tied to the operating program, since it is principally concerned with problems on product use or modifications.

In developing a research program it is necessary to determine the balance between different activities under the overall research program. What programs should receive what amount of emphasis over what period of time? In existing research programs, once a program has been initiated it tends to continue under its own momentum, frequently beyond its useful life, to the detriment of other needed research programs. The balance of a research program is not a one-time activity but a continuing process that should be reviewed periodically as part of a long-range research program.

In translating research goals into specific programs the time factor must be considered. It is easy to fall into the trap of believing that a problem can be overcome if only enough funds and staff are devoted to it. Knowledge is evasive and requires time to mature. Management must recognize this maturing process in research and should not expect immediate results. Research is more like agriculture than industry. In industry, greater efforts can be quickly translated into greater output. In agriculture, it takes time for plants to mature and thus process cannot be substantially accelerated. Unless management recognizes this about research, there will be continual frustration with the comparatively slow rate of development of knowledge. Management may recognize the need for research, and operating personnel may supply researchers with problems to solve, but the principal source of ideas is the researchers. As one industrial research administrator has said, "The success of the research program depends upon two things: first, management must feel a need for research, and second, it must procure good research staff, for without the creative researcher it can spend millions and still have nothing."

In planning a research program, consideration must be taken of lead time. The more theoretical or basic the program, the greater the time required to bring the research findings to an application stage. Where research programs affect a substantial segment of the population or environment, lead time may be 30 years or more.

How Do You Select and Control Research Projects?

Criteria must be established for the selection of projects and the assessment of the probability of success and expected gains under the constraints of staff, facilities, and funds. The degree of formalization of the research proposal process depends to a large extent on the size of the research program and

whether projects will be done by in-house staff or let to contractors. Contracts for research require substantially greater details as to the obligations, responsibilities, and liabilities of the contracting parties.

Probably 50 to 75 percent of the research proposals will emanate from the research staff. Those responsible for administration of the research program must determine who will select the projects to be undertaken. Management usually designates research administrators or research committees to select the projects. To be creative the researcher must be intensely interested in the projects he is working on. At the same time, management will desire a certain type of research program that may or may not be compatible with the researcher's interest. Where there is no interest by the researchers, it may be better to recruit additional staff than to force researchers to work on a project in which they have no interest, or the project should be done by contract research.

Priorities, schedules, and backlogs of research projects should be considered. One of the limitations in the magnitude of the research program is the availability of staff. The researchers and administrators can generally keep project proposals well ahead of staff time available to perform the research. One advantage of setting up a backlog of research projects is that it helps shorten the lead time required from the point of proposing the project to the actual initiation of research. With a project approved, the researchers may quickly get into the process of developing a detailed working plan for funding. Advance scheduling becomes extremely important in the developmental stage of the project because of the massive amounts of manpower and materials that must be obtained and scheduled.

How Large Should a Research Project Be ?

The optimum size for research projects and the time estimate for project completion must be considered. There has been a recent tendency toward large-scale short-term projects in government research contracts. It is hoped that the large-scale projects will be better able to view a larger portion of the problem than a series of small projects could, and will more quickly lead to a resolution of the problem. The task force approach is often used. This approach may be feasible where the primary emphasis is on the developmental stage rather than the basic research stage. It may also be useful where the research depends on gathering masses of data and analyzing them. However, if the research requires a great deal of creative thought by the researchers, the size of the project is better tailored around the individual researcher and his required staff support. Large-scale research projects can be broken down into subactivities and tasks and delegated to individual researchers. The results of the individual research efforts must then be combined and synthesized into a final project summary. In this manner the large- and small-scale research projects differ very little since each must be broken down to the researcher-oriented project size.

The real problem with large-scale short-duration research projects is the utilization of research staff upon the completion of the project. Where projects are small and researcher-oriented, the discontinuance of any one project does not affect a large portion of the research program. On the other hand, if the project requires a substantial portion of the research staff, the discontinuation of the project may have some severe effects on the staff and the funding of a continuing research program.

Therefore, management must determine whether it intends to support research on a project-by-project basis or on a basic foundation program. Under a foundation program, the research level would be relatively constant and the

research staff could be developed on a career basis. If the research program is on an individual project basis or is allowed to fluctuate with the availability of funds, it may cause a basic insecurity in the research staff and make it difficult to develop a career-oriented group. For this reason, it may be better to hold the research program at the more constant level even at the loss of short-term opportunities. Perhaps the developmental stage may be allowed to fluctuate more since it is more dependent on massive manpower efforts and less on individual creativity.

In developing a new research program, management must be willing to sustain the research program for a period of growth during which there is little payoff or return on investment. Just as many businesses fail during their early stages because of a lack of working capital, so research programs are susceptible to failure for lack of continued funding or confidence by management during their early stages of development when there is little payoff.

Where Should the Responsibility for Research Be Located?

The location of responsibility for the research program will have a substantial effect upon the content of the program. In establishing responsibility for research, consideration should be taken of (1) the universality of the research problems; (2) agencies interested in the research topics; (3) the location of necessary resources; and (4) the organization that can accomplish the program at the least total cost. The more important a program is and the more effect it has on management policies and decisions, the higher in the management hierarchy it should be located. This is why research that will have long-term effects on the future markets and profits of a company should be located close to top management. Application problems may be located closer to the operating agencies. This distinction is not exact and research agencies doing application-type research often have basic research mixed in. Similarly, organizations doing theoretical research are often asked to resolve operating problems. The key is to locate the research program close to the management decision-making source. If the appropriate level of management does not have an interest in the research program, it will not give it substantial support or backing.

The location of the necessary resources also will have an effect on the location of research responsibility. Many research programs have developed gradually, often as a result of testing functions that require highly trained staff and testing equipment. As research programs grow from their embryonic stage, competence is built up to perform specific types of research. When research is formally recognized by management there is a natural tendency to locate it where there is already existing competency.

There is a question as to whether operating units should perform research activities in addition to their normal functions, especially where research tends to be of the problem-solving type. While this may have the advantage of locating the research activities close to those needing the results, it has a number of liabilities. Generally, the type of personality interested in research is different from the type interested in daily operations and management activities. When the organization is asked to perform dissimilar types of activities, either the research or the operational phases may suffer, depending on the immediate needs or management orientation. Usually it is the research phase that will suffer, especially if there is a shortage of staff or funds, since the operating program must be continued. By locating research as a separate program from the operational activities, the reduction of the research program because of a limitation of resources is at least clearly defined for management.

The saying "out of sight, out of mind" applies to research. Where a continuous communication between research and those making policy decisions does not exist, there is a general tendency to discount the value or importance of research.

What Conditions Are Conducive to Research?

It is necessary to develop an environment conducive to research in order to develop a competent research staff whose members work to the best of their creative abilities. This may be achieved by sufficient funding and willingness of management to back the program without pressure for immediate payoff. At the same time, however, management must see that money will not be wasted and will assist in achieving the goals of the organization. While the research program may be oriented to resolving problems and achieving goals of the organization, management must recognize that the key to success is the researcher and that the research program must be designed to encourage the uniquely creative capacities of the individual researcher. To do this, management must understand motives of researchers and must understand its own motives. It is necessary to integrate both to achieve the best interests of the organization. Management must recognize that all interhuman relationships are based on a bargain between the two parties. Both management and researchers are naturally prone to project their own motives and desires upon the total environment and sometimes fail to understand when the rest of the organization does not react the same way as they do. One of the principal causes of strife between management and researchers is a lack of understanding resulting from faulty communication.

How Do You Coordinate a Research Program?

Coordination is based primarily on communications. The different degrees of centralization or decentralization of the organization, the location of research responsibilities, the organization of the research program under function or product lines, the coordination of the research program between two or more agencies, the use of in-house and contract research are all dependent on an effective two-way communication system. Students of management are aware of the importance of communication networks and the psychological interrelationships between management and the workers. In modern society, cooperation rather than command is the key to achieving the objectives of an organization. The resolution of such questions as the centralized control of research, both in-house and contract research, the combination of research and testing facilities, and the use of research coordinating committees must be viewed, not in terms of formal organizational structure, but in terms of communication systems and whether they will promote or impede the goals of all agents involved. Where once classical organization theory stressed formal one-way chains of command with elaborate definitions of scopes and functions, management behaviorists today recognize that the real structure of the organization is a combination of the communications system with the decision-making structure.

Among researchers and research administrators there are sometimes strong feelings as to the location and coordination of the overall research program. Some would like to see the program highly decentralized, allowing the research decisions to be made by all the individual agencies participating in the program. Other research administrators would have a strongly centralized research program in which all in-house and contract research is channeled through one authority. There is often great jealousy and competition between

in-house and contract research. The location of responsibility of the research program within the formal organization structure may be indicative of the value put on it by management.

What Are the Values and Limitations of Research Advisory Groups?

Committees are often relied on for advice in the coordination of research. Frequently, a wide diversity of interests and various levels of management are reflected in such advisory groups. In developing a research program, the uses and limitations of advisory groups should be considered. Advisory groups, like all committees, have certain functions that they can perform effectively and others they should not perform. They are of value for such activities as stimulating interest, eliciting general comments on a subject, providing multiple-channel communications, and disseminating information in general. Their primary activity is communication, not decision-making. If committees are asked to decide on a course of action, the decision is often the least objectionable to all members rather than the best solution. Committees are not expeditious means for arriving at decisions and they are generally not highly creative organizations. In research programs, when committees are used as the primary decision-making bodies, they may become merely a nominative group that approves the recommendation of the research administrators or of a strong individual or coalition group of the total committee. In developing a research organization, care should be taken to decide what results are desired from an advisory committee.

Research management utilizes executive committees, program and project advisory committees, long-range planning committees, research review committees, and liaison committees. An executive committee usually includes members from middle and top management and generally considers problems of program size and direction. Because of its broad interests it is usually not the appropriate group for the establishment of specific projects or project priorities. If the executive committee is used for the approval of specific projects it may tend to become too involved in research details and to lose sight of its overall function of determining the goals and the direction of the program. The designation of projects and priority schedules as well as the development of project content is better allocated to program or project committees. Where a research program is large, both a general program review committee and a specific project committee may be desirable. Where the number of projects is limited, both activities may be performed by one committee.

Sometimes, because of the size, complexity, or geographic location, it is desirable to set up a liaison committee composed of research administrators and principal researchers as well as technical experts within the subject field to keep a current review of the progress of the research projects and to assist in any problems that might arise during the project. Many organizations utilize research review committees to review the progress of research activities periodically. If the committee membership is broad enough, it is a good medium for communicating research findings to people who might be in a position to put them into practice. It is also an extremely good sounding board against which the researchers are required to crystallize and articulate their research progress and to defend their research techniques and data. Such a research review committee, if it represents all areas within an organization interested in the research, offers a good two-way communication system between the researcher and the user.

One of the problems in utilizing committees is the difficulty in locating responsibility for decisions. For this reason many research organizations, in addition to using a committee structure, rely on a separate administrative

decision-making structure in which individuals are made responsible for decisions. The balance between the influence of committees versus individual administrators on the research program is principally determined on the personality strengths of the individuals involved and the exigency of the situation. Where time is essential and there are strong, decisive administrators, research advisory groups will play a secondary role. Where time is not extremely important or where management does not feel a vital concern about research, research committees will exert a greater amount of influence. Where strong administrators are also members of the research committees, they will influence the committees to arrive at their point of view.

What Are the Values of In-House Compared to Contract Research?

One of the research management problems that has been difficult to resolve is the balance between in-house and contract research. The allocation of funds between contract and in-house research is usually determined by management on the basis of matching the availability of research staff and funds against the desired program. If the necessary staff and facilities can be generated within the organization, all research may be performed within the organization. On the other hand, all research may be contracted out to independent research agencies. Most frequently, research programs depend on a combination of both in-house and contract research. If management depends solely on contract research, it does not have as close control over the research project as it could if it were done in-house. However, by utilizing contract research, management need only buy the amount of research it currently desires and thus can have a highly fluctuating program. One of the problems of using contract research is that management may have difficulties in finding anyone capable or interested in performing the desired projects.

Research, like many other management functions, frequently follows a concentration pattern in that the programs tend to be heavily concentrated into a limited number of areas over a given time period. In organizations that cannot employ a complete research staff, the usual procedure is to develop an internal research organization capable of handling the areas of high concentration and to utilize contract research for special areas for which they do not have competent staff or adequate facilities. Contract research is sometimes used when a new broad-based program is undertaken and there is not sufficient time to develop an adequate in-house research staff. If the program continues for a substantial length of time, the general tendency is to develop proficiency within the organization and to transfer the activities from contract to in-house research.

Because in-house research should be relatively stable, contract research may be reduced when it becomes necessary or desirable to decrease the research effort. Where such a program reduction is necessary, management must review the programs and assure itself that it is not defeating its objectives and continuing a research program in-house that no longer reflects the organization's needs, while discontinuing a contract research program of vital interest merely because it is more sensitive to budgetary requirements.

What Is the Relationship Between Research and Development?

Just as in-house and contract research overlap each other, so do research and development activities. If we define research to mean the evolution of new knowledge, development is the translation of the knowledge into practice or use. Research in this case is directed more at the thought processes: the creation

of new concepts and theories, new processes and inventions. Development is the formulation of procedures and technology for putting the new discoveries into use. It is difficult to clearly distinguish research from development and to separate research scientists into either exclusively research or development activities.

Management, while it may desire to set up a distinction between the research processes and the development processes, should not prevent the research scientist from also participating in the development stages or to prevent those involved in development from also undertaking more theoretical or basic research projects. In some industrial research programs this fact has been recognized by permitting and encouraging a certain amount of basic research in the programs of operational divisions. The research staff that is devoted to theoretical research and is more or less segregated from the normal activities of the organization is asked from time to time to assist or advise in developmental or operational problems encountered in the field. This interchange between theoretical activities stimulates the researcher, and productivity generally is higher than in situations where this interchange is not permitted.

Research activities generally tend to be individually oriented. Development activities may require a massive amount of funds and staff. Often research programs do not put enough emphasis on the developmental stage. Even if the product of the research program is the development of new knowledge not requiring expansive development of hardware, development costs may be high because it takes substantial resources to provide the educational programs necessary to change the attitudes and behavior of a large organization. The staggering costs of development cause many research programs to concentrate at two extremes: (a) the development of new knowledge without its application, and (b) the resolution of operating problems. This lack of allocation of sufficient resources for development has caused a gap between technical knowledge and practice, especially in government research where the outcome of research is not reflected in future profits as it is in industry.

As society continues to grow and become more complex, the developmental costs and the lead time necessary for translating knowledge into practice will increase. The problem of translating research into practice will become even more difficult, especially in government activities, which generally have a wide impact on the environment. The tremendous cost of the current space or defense programs is extremely small when compared to the developmental costs necessary to institute any basic changes in national public programs such as transportation, education, health, or welfare.

Of What Value Are Cooperative Research Programs?

A number of governmental agencies have utilized the technique of cooperative research programs to pool their limited resources. A cooperative research program permits a program that no single agency could afford through its own resources. Its limitations are that it usually must rely on contract research and there is no single agency responsible for its supervision or control. Since there may be a number of contributors of funds to the program, its management will suffer the same constraints that the use of committee management does. In considering the use of cooperative research programs, management should decide who should control the program and by what administrative techniques, how long the program should be continued and how it will be funded if one of the cooperating agencies discontinues its participation or wants a special facet of the program expanded.

The problem of ownership is intrinsic in all research programs. Who is to reap the rewards of new discoveries or ideas—those who made the discovery, those who promoted the discovery through the developmental stages into use, those who financed the program, or the general public? More and more where public funds are used to finance a research program, discovery rights become public property. The possibility of financial remuneration is not used as an incentive. In industry, generally as a part of the employment contract, research findings belong to the company rather than to the researcher. This is also true in academic and governmental research.

How Are Research Projects Initiated?

Management must rely on the researcher as a primary source for project ideas. Even in research programs that are heavily oriented toward problem-solving, the researcher rather than the operating engineers and administrators generally is the principal source for research topics. Research topics suggested by operating or staff agencies tend to be of three types: (1) problems for which there is already technical knowledge, (2) problems too broad to be handled within the research program, and (3) problems that are of a troubleshooting rather than a research nature. Because of their lack of familiarity with research, operating personnel are often inarticulate about their research needs. The researcher, if he is kept in contact with daily operations, may be in a better position to articulate the problems in terms of research proposals. In addition, problem-solving research is generally two-sided. Answers are needed to specific problems, but if the problem is to be kept from recurring, not only must this specific problem be resolved, but the basic underlying factors must also be understood. Problem-solving projects may ultimately lead to the development of theoretical research proposals. Research programs tend to be self-perpetuating, and the resolution of one project often precipitates similar projects to delve into other facets of the problem.

How Should Research Proposals and Projects Be Evaluated?

The contents of research proposals and the administrative procedures for their evaluation vary among research organizations and the personalities involved. Where there is good two-way communication between the researchers and research administrators and a feeling of mutual trust and competency, research proposals may be of a very informal nature. Where these conditions are absent, proposals are more detailed and the review and evaluation process more formalized. Since the research process is ultimately dependent on the capability and efforts of the researcher, no amount of formal review processes and working plan design will assure satisfactory results in the absence of a competent, creative, and dedicated research staff.

Generally, research proposals contain a description of the research, the scope of the program, the methodology and experiment design, the techniques used to validate the findings, the necessary personnel and equipment, a list of the researchers who will be assigned to the project along with a biographical sketch and the proportion of time that they will allot to the project, and a proposed time schedule for completing different activities under the project. The principal difference between the research proposal and the working plan is in the degree of detail. The cost of developing a detailed working plan both in terms of money and staff time can be very high; therefore, unless there is some certainty of undertaking the research project, project proposals are not worth developing into detailed working plans. This is especially true where there is competitive bidding for research contracts. The costs of developing

a working plan may be financed either by approval by the sponsoring agency to proceed based on a proposal, or such a plan may be included as an overhead cost in the research contract.

Sometimes formal criteria are set up for evaluating research proposals, especially contract research. In reality, the reviewer makes a decision on how well the research proposal conforms with his understanding of the research goals and programs and whether the project design is similar to one that he himself would utilize if requested to perform the research. The other principal criterion is his evaluation of the capability of the research staff to perform the proposed project successfully. His knowledge of the research capability may come from his own experience with staff personnel, with others who have knowledge of their capabilities, or from written description of their experience and background.

One of the problems, especially in contract research, has been that often the research is not done by the designated principal investigators, but by less experienced staff under the general supervision of a principal researcher. The result is that although the program follows the general pattern set forth by the principal investigator, the subordinate researchers, who do not have the same wealth of background and experience, must first develop their own knowledge in the field before they can proceed with the advanced research that the project demands. Since the development of the basic background or knowledge takes both time and money, either the project will not achieve the desired results, or it will require greater allocations of time and funds. The use of the technique of having research performed by neophytes under the guidance of a principal researcher is a good teaching device and may provide a source for future researchers. However, if it is not clearly defined in research proposals, management may not understand that the research project is serving the dual function of education and the advancement of knowledge, and the sponsors may feel that the research is not providing a fair return on the investment.

Inasmuch as the success or failure of any research project lies with the capability of the principal researcher management should demand assurance, in approving a research proposal, that there will be some provision for keeping the research project going if the organization loses the principal researcher. If the research is such that it cannot be immediately continued by other research personnel, the project should be designed in phases that may be completed within given time units, so that a loss of the researcher will not result in the loss of the total project. This requires more than merely keeping progress reports of the project. It requires a clear definition before the research project is initiated of the step-by-step procedures that will be taken to complete the project. As each step is accomplished, the results should be recorded in such a way that if the project loses the researcher the loss to the total project will be minimized, other researchers taking over the project will know not only what has already been accomplished but what the next scheduled phases of the project are.

Thus, though research proposals may be kept short because of the cost involved in their preparation, management should be assured that there is a detailed working plan for each project before the project is actually undertaken. In addition to assuring that the experiment or theory has been thought through, the use of a detailed working plan will help proportion the research efforts. Without it there is a tendency to concentrate too much effort on the beginning phases of a project and not enough at the end because of a lack of funds or time. Also, setting projects up into phases allows them to be modified over a given period of time to reflect new information and needs.

Research, like other human endeavors, is sensitive to fads. As the individual's, organization's, or society's interests shift, there will be a shift in the research program. Although there may be many areas needing research it is only natural to expect that those attuned with the times will receive the greatest interest and emphasis. In developing an overall research program, management must keep in mind that fads are generally short-lived. It must incorporate into the research program not only fads but also the less popular research needs. Management must also be willing to back research that is not currently popular but that will be needed in the future.

The larger the project and the longer the period it is to continue, the greater is the effort required in preparation of the proposal, and the greater the effort necessary to integrate the overall project prior to its inception. Large-scale, short-time projects sometimes do not allow adequate time to develop the research systems, staff, or maturation of knowledge to assure a fair return for the funds invested. Therefore, the lead time necessary for well thought out large-scale research projects may be considerable. This means that not only must management determine the time that it would like to have the research results, it must also plan for the necessary lead time to develop proposals and working plans; undertake the actual experiment; develop the necessary hardware, staff, and procedures; and successfully market the idea. Sometimes research is criticized by people who do not realize the amount of time it takes to bring a research proposal into fruition. From a public relations standpoint, it might be advisable to integrate short-term projects directed toward current fads and interests into the overall research program.

How Is the Research Program Financed?

Sometimes in the development of a research program little consideration is given to the effect that the sources of funds will have on the program. An administrator who controls the sources of funds for the research program will directly or indirectly control the overall program. In fact, this is management's key technique in controlling the research program. Through the allocation of resources, the program may be altered or diverted through administrative procedures. Any administrator who has authority to endorse or prohibit the flow of funds into research has control over the program. Sometimes legislators have found that funds they have appropriated for specific purposes and programs have been redirected and diverted by administrative interpretation. The budgetary authority to expend funds is essentially a negative power in that it may prevent the use of funds for programs and projects, but it does not have the alternative of authorizing funds for new programs.

The fund structure itself may affect the research program. Where funds are earmarked for specific purposes, they become relatively insensitive to changing needs and emphases. By earmarking funds for research, an advantage is gained in that research is not in competition with other programs that may be of more immediate interest to operating managers. The earmarking of funds makes the research program more independent of the rest of the activities of the organization. However, with this independence come liabilities. One liability is that, in not being in a competitive position with other activities, the research program may not be in proper balance with the overall functions of the organization. It may be receiving too little as well as too much support. On the other hand, earmarking funds provides a basic foundation program on which to build a continuing research program that is not sensitive to raiding by other activities.

Because it is difficult to measure the value of research, especially long-term research, it is difficult to establish the criteria for allocating funds to

research in terms of measures of performance. In most instances, since the development of a research program is a gradual process over time, the allocation of research funds is based on previous rates of expenditures plus allowances for new programs. In other instances, the allocation of research funds is based on percentage figures or other arbitrary bases not directly related to the research needs. What is needed in a research program is a source of guaranteed funds to support a minimum program as well as additional funds for emphasis in current areas of interest. The use of a foundation program plus additional funds provides management with the opportunity to curtail additional funds if the research program is not sensitive to its needs, while at the same time it protects the researchers from having to comply absolutely with the wishes of management for fear of having the total program eliminated.

What Are the Necessary Accounting and Cost Control Systems?

In developing the budgetary accounting and cost control system for use in connection with the research program, management must consider how tightly project cost controls should be exercised and on what criteria they should be established. If costs are not a key factor or if there is an excess of unallocated research funds, project cost controls tend to be lax, especially for individual projects and are more generally in terms of programs or total expenditures for research. As funds become increasingly scarce, tighter budgetary controls will be utilized. If performance units cannot be established to measure a project, then the adherence to tight project cost controls is merely the adherence to the arbitrary decision of how funds ought to be allocated.

If project cost controls do not readily lend themselves to actual direction and control of the research program, they are helpful in measuring the progress of a project and often indicate a point of no return where a project may be discontinued. Researchers have a tendency to keep projects on the books so they may be reactivated should the need arise at some later date without having to go through the formal procedures of project proposal and approval. Project cost control statements may indicate this situation and precipitate a management review of the project.

In spite of its limitations as a control device, the budgetary process is an effective planning tool. It is more important for contract research than for in-house research. In-house research projects are subject to other control devices that are more effective. With contract research, budgetary reimbursement for research becomes an important device for assuring the completion of the project. Most research projects provide for a monthly billing procedure for work completed, but set aside an amount that is not to be paid until the project is completed to the satisfaction of the sponsor. One of the current budgetary cost problems in research is the high overhead costs charged to projects. These overhead costs may be as high as 50 or 100 percent of direct costs, and there is no easy way for the contractor to ascertain whether they are valid or not.

How Can We Communicate or Retrieve Research Findings?

With the tremendous rate of growth in research in all fields, there is the continuing problem of communicating research findings, not only within the organization, but to other agencies involved in similar types of research. This is particularly true with governmental research. It has been estimated that rate of knowledge is doubling every ten years. In the United States alone, there are several million scientific journal articles, books, and manuscripts published every year. Even if he wants to, it is impossible for a researcher to

keep abreast of all the developments in his field. Recent advances in electronic data processing, storage, and retrieval systems are attempting to handle the massive process of locating ongoing and completed research in specific areas. However, the problem of sorting through the mass of literature to extract the important information has not been resolved. This is still left up to the individual researcher, and even if he is provided with sources of information relating to his field of research, this process may be so time-consuming that it may be cheaper to reproduce the research in its entirety rather than search out and verify research done elsewhere.

There is, in addition, the problem of assuring the validity of research done elsewhere. Researchers may be reluctant to accept research not done under their own supervision. Not only is there a need to develop a storage and retrieval system for research information, but as part of this system, there is a need for sorting out important findings and verifying the results.

In recent years there has been increased use of conferences and symposia as techniques for communicating research findings to the scientific community. Face-to-face contacts among researchers allow them to quickly distill the essence of other research programs and verify them through two-way question and answer systems. It allows the researcher to judge the caliber of the other researchers and the validity of their results.

If communication of research findings is difficult among similarly oriented researchers, it is even more difficult between researchers, management, and the community. Research findings may never be utilized because they are not put into terminology that can be understood by those who can use them. Management should be concerned that research is translated into a form that can be utilized by potential users. Within an organization, this may be done by committee meetings or conferences in which researchers discuss their work and findings with administrators and potential users.

What Are the Sources and Criteria for the Selection of Research Staff?

The recruitment of researchers and the criteria for their selection have been continual problems for management. Many types of selection techniques have been proposed but at the present time there is no procedure that will give a high predictability of success. Psychological and performance tests provide an indication of a candidate's performance in given limited situations. Education and training, while they may provide indications as to the candidate's performance in an academic atmosphere, may not provide a reliable criterion for determining research capabilities. The candidate's working experience shows his past field of endeavor but may not show the area in which he has the greatest potential creativity. Competitive examinations and written tests may not be good measures of the characteristics necessary to be successful in the research situation. Thus, while all of these factors enter into the selection of a candidate, none of them are sufficient to predict his potential accomplishments.

Thus, the criteria for selection should be dependent on the need to eliminate candidates before they have had an opportunity to demonstrate their abilities in the actual research environment. If research candidates are in oversupply or if the costs are too high to permit the candidate to demonstrate his capabilities, then sufficiently selective devices must be designed to provide only the number of candidates that the organization can accommodate. If costs of facilities do not have to be considered, the ideal situation for the selection of researchers would be to provide an opportunity for all candidates to demonstrate their capabilities. Their own lack of interest or demonstrated inability would then be the principal criterion for eliminating them from the research program.

Sometimes, however, the criteria for the selection of research staff are not based on a need to minimize cost or overloading of research facilities but rather on ego images and vested interests of those setting up the criteria. Research is no different from other professions in that the professionals like to establish the criteria for recruitment and measures of success according to their own knowledge, experience, education, and qualifications. By defining their own qualities as those prerequisite for success, researchers or administrators automatically define themselves as being successful. However, history demonstrates that often one generation's failures are the next generation's successes. The arts and sciences are replete with examples of how the truly creative person was rejected by his own society.

Perhaps in research more than in any other field, the individual must be sensitive to changes in the environment or field of knowledge far in advance of the general community. Where a researcher is dealing with lead times of a generation it must be expected that the consensus of the present community will not be sensitive or favorably disposed toward the researcher's ideas or capabilities. Where the research function is, however, directed toward solving existing problems or is of a highly applied nature, current criteria for selection may be more valid in terms of their predictability of success. Often the research program is limited by the criteria for the selection of staff. If the criteria for staff recruitment are such that they accept those researchers competent only in applied or problem-solving areas, then a theoretical research program will not be possible regardless of management's desire for one, because the existing research staff will not be available, and the recruitment of additional staff will not provide the necessary characteristics.

Management should give careful consideration to such questions as the following:

- How much weight should be given to education versus experience in recruiting employees?
- Should the staffing of research departments be handled under the same classification system as the recruitment for regular operating employees?
- Should the criteria for the selection of all researchers be the same, and if not, what should be the criteria? In what ratio should the different types of researchers be employed?

Management should look at each criterion carefully to determine first, why it is needed, and second, what its effect will be on the development of a qualified research staff and on the long-term research program of the organization.

Usually, it is easier to obtain research funds than qualified researchers. If young professional people are not immediately attracted into the research area the probability of attracting them at a later point in their career is small. Because of the lead time necessary for the development of a competent professional research staff as well as lead time necessary for the completion and implementation of research, management should continually evaluate and forecast needs for research personnel. Because of the scarcity of professional research staff, the professional researcher should be provided with sufficient technical and clerical staff so that his time is not allocated to activities that can be done by subprofessional and technical personnel.

How Do You Provide for Career Progression in Research?

Along with developing a recruitment system, management should also clearly define a career progression system for researchers. In some organizations, research is looked on as a dead-end street, and if the researcher is

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to progress in his profession, he must leave research and go into other operational functions of the organization. In many organizations, salaries and career progression are based on administrative responsibilities. The larger the number of people or magnitude of program that the individual is responsible for, the higher in the organizational structure and the larger the salary received. In recent years, this concept has been undergoing a change, and today there is greater recognition of the distinction between administrative capacities and technical competence. A highly creative individual who likes to work in semiseclusion may be a very valuable asset as a researcher but a failure as a research administrator. Unless provisions are made whereby a man can make a lifetime work of research, there comes a point in his career that if he is to advance he must leave research activities and assume administrative responsibilities.

Management's ability to deal effectively with the human as well as the physical environment is becoming a highly specialized art requiring professional training as well as interest and inclination. The difference between a researcher and a research administrator is not so much the inability of the researcher to learn management techniques, but rather a difference in interest. As long as management puts higher rewards on administrative functions than on the performance of research, the ambitious researchers will strive to become administrators. If adequate satisfactions, recognition, and remuneration are provided within the research framework, then a competent researcher will not shift out of research into other activities.

Because of this isolation of the research function from the central activities of the organization, management should consciously make an effort to make the researcher feel that he is a part of the overall organization and stimulate him to participate not only in the activities of the organization, but also in professional activities outside the research organization. In this way the researcher will identify not only with his internal group but also with the total professional environment.

Many organizations use some form of performance rating system to evaluate their employees. These rating systems are used in considerations for salary increases or promotion based on the belief that a supervisor can effectively evaluate the individual's performance and usefulness to the organization. If the organization is sufficiently small and two-way communication between all members of the staff is possible, the need for a performance rating system does not exist. However, as an organization grows the communication network increases at a geometric rate and it is impossible for management to know each staff member individually and be able to evaluate his productivity or usefulness to the organization. Therefore, rating systems have been developed to provide management with some form of evaluation of performance on which to base salary increments and career advancement.

The use of effectiveness or performance rating systems for employees is closely tied to management's philosophy toward salaries. In a shortage economy of past decades, salaries were heavily relied on as the primary motivating factor for work. In an affluent society the motivational value of money rapidly decreases. As an individual's expectations for current consumption are satisfied and as his long-term expectations and provisions for security are taken care of, the value of money decreases while other motives increase in importance.

If a researcher's interests are to continue to expand throughout his career, management must see that he is provided with ample opportunities for stimulation by new ideas and opportunities. Training programs, participation in professional organizations, and conferences are some of the techniques for

keeping abreast of current ideas and developments. Typically, the operating staff is less interested in reflective thought processes than are researchers. Unallocated time should be provided for researchers to delve into new ideas and to catch up in their own field of specialization.

Some of the decisions that management must make in establishing or evaluating a research program have been discussed. First, management must feel a need for research. Second, it must clearly define the research goals and programs and translate them into time-scheduled plans. A research organization must be established, funds provided, and a staff recruited. Procedures must be developed to achieve the maximum benefits of research by translating research findings into practice. Management must understand the researcher and his motives and provide a situation in which both management goals and the individual's goals can be mutually achieved.

State Highway Research Organizations

Highway departments have made use of contract research with universities and consultants and have created in-house research units to perform needed research. Most highway research programs use a combination of in-house and contract research activities. The emphasis on contract on in-house research varies among the states according to the highway department's attitude toward research, the availability of departmental staff to perform research, and the interest of the universities in performing highway-oriented research.

Some states, such as Texas, Ohio, and North Carolina, depend very heavily on contract research with the state universities for their research needs. The respective state universities have been anxious to obtain highway research contracts and there has been sufficient interest on the part of the faculty to obtain adequate staff capability. Other states, such as New York and California, although they contract for some research, rely principally on in-house research organizations to accomplish their research needs. Still other states, such as Illinois, Virginia, Louisiana, and Michigan, employ varying combinations of in-house and contract research in their programs. If a state has a large, well-staffed materials testing section, it frequently develops a research section in the materials laboratory, which develops into an independent unit as research becomes more important (Virginia and Missouri are examples of this). Sometimes the research activities are concentrated into a single research unit; sometimes they are distributed among the operating agencies. Where research programs have been problem oriented, the general pattern has been the development of in-house research units, with emphasis on "payoff."

Recently, there has been a trend away from contract research with universities. Much research done at universities has been in conjunction with graduate student thesis requirements. Some highway departments have found that academic and graduate student research was not sufficiently responsive to highway department operational needs, and so as planning research funds have been in greater demand for other highway activities, funds for contract research with universities have been curtailed. At the national level, the size of the projects has increased and the length of time available has become shorter, with the result that many universities are not equipped to handle them. With the enactment of the 1962 Federal Highway Act, research and planning were given additional emphasis. In addition to planning survey activity already in progress, the Act required development of urban transportation studies for all cities with over 50,000 population. The new planning activities, along with the development of the Interstate System, have demonstrated the need for research in the field of transportation system planning and for the effective utilization of planning. Within the last ten years a number of states have developed special research units in response to planning requirements. Where states have very large metropolitan areas, research funds may also be provided by the highway departments to urban planning authorities.

A typical state highway research program today has probably been developed according to the following rationale: Since the research program is primarily supported with Federal-aid funds, the research budget may be administered by the unit within the highway department responsible for Federal-aid planning and research funds. This is usually the planning department. The in-house

research organization will be directed to problem-oriented physical research and may be closely allied to the materials testing functions. A special unit may be devoted to planning and urban research problems. Where there are research-oriented state universities, research contracts are usually apportioned to them.

Where the research problem is of an application nature, the agency within the highway department affected by the problem will show an interest in the project and in applying the research findings. Where the research is not specifically directed at problem-solving, highway management has generally shown less interest in putting research findings into practice, although there is a strong trend in the American Association of State Highway Officials and the Bureau of Public Roads toward improving this situation.

The development of research programs has been primarily initiated by field personnel who have specific problems. Probably more than half the funded research projects result from proposals by the researchers. The final selection of projects has been based primarily on the interest of the highway department staff, with management exercising veto power rather than direct control.

The research projects have been usually directed around efforts of a single individual with a support staff and have usually been in the range of \$20 thousand to \$30 thousand. Like research activities in most organizations, once a project is initiated there is a tendency to continue it for several years. The research program generally develops around the specialty of the in-house or university research staff. Therefore the emphasis of research programs differs not so much because of differing problems but because of differing staff capabilities and interests.

The development of research programs and selection of projects varies among states. Some states have highly formalized procedures for selection and review of research projects; others are very informal.

In states that have had a research program, either in-house or under contract for a number of years, there is a general recognition of the need for a sustained level of research expenditure and an awareness that support of research on a project-by-project basis inhibits development of a career-oriented research staff. Indiana, Illinois, Texas, and North Carolina have established foundation programs with the state universities so that the university may develop a continuing and predictable research activity. In other states that have not developed a foundation program, research is generally on an individual contract basis and there is little sustained effort between the university and highway department. Projects tend to go to specific faculty members for specific topics.

The in-house research program has been based primarily on availability of staff. Staff recruitment and retention in highway research organizations has been one of the critical problems. In addition to designated research organizations within the highway department, operating units may develop research projects within their activity. For example, California has maintained a substantial research program within the right-of-way and other operating divisions for a number of years.

States with continuing research activities dating back for several decades formerly relied on primarily state funds to support the research program. While portions of the research programs in several states are still entirely funded by the state, the majority of research now is supported with Federal-aid funds. Approximately one-third of Federal-aid allotments available for planning and research are used for research. Thus, the nationwide expenditure of Federal Highway Planning and Research Funds (1½ percent funds) for research amounts to over \$20 million annually. In the allocation of funds between

planning and research, research generally takes the last dollars available rather than the first. With growth of funds allocated for urban transportation planning there has been a decrease in funds available for research. Since 1962 up until the last two or three years, most states had a surplus of planning and research funds and were willing to entertain research proposals from university and outside contractors. As funds have become increasingly scarce, there has been a general trend toward limiting contract research and emphasizing in-house research on operating problems. When funds were relatively ample, there was little concern for project cost control or for discontinuation of unproductive projects. As funds become scarcer a tightening of budgetary controls can be expected.

A number of techniques and organization structures have been developed for the coordination and control of research. In states that do not have a large in-house research program, such as North Carolina, Iowa, and Ohio, small research coordinating units have been established (often under the planning division) to maintain budgetary controls, to provide liaison with contractors, and to comply with administrative procedures required for use of Federal-aid funds. In Illinois and Virginia, where the states have large in-house as well as contract research programs, formal procedures are used for the coordination and review of the research program. Almost all states with large in-house or contract research units have designated research coordinators. States that do not have large research programs usually have someone (often in the planning department) who is charged with the additional responsibility of maintaining budgetary and administrative control over research.

Advisory groups are often used to review proposals, coordinate research, and communicate research findings. Illinois and Virginia have developed formal programs for reporting research and for evaluating research proposals. Top-level administrative boards have been designated to review basic and operational problems of research units. Advisory boards and committees have been established to review ongoing research and to consider new research proposals. These committees are also used as a means of communicating research findings to operating personnel. The selection of membership on these advisory committees is often quite broad, including several levels of management.

In addition to general review boards and committees dealing with total research programs or specialized areas of interest, some states, such as Illinois and Ohio, create project committees. Members are selected to assure that potential users of the research are kept abreast of the activities of the project and participate in the research planning. New York, Kentucky, and California, which have sizable in-house research programs, do not rely heavily on formal advisory groups for dissemination of research findings or for guidance of research activities. Such states rely heavily on personal contacts of the research staff with operating personnel to communicate research findings directly and get them into practice. Where research activities are conducted within operating agencies, there is a close communication of research activities with operating personnel.

There has long been a recognition that similar research problems may occur in several states regionally or even nationally. One of the basic missions of the technical activities staff of the Highway Research Board has been to provide liaison and an exchange of information among states with parallel concerns. In several instances states have combined and jointly financed large-scale research projects. In addition, through AASHO, the states support the National Cooperative Highway Research Program administered by the Highway Research Board. This program seeks to identify and study major research problems

common to a majority of the states that are suitable for inclusion in a cooperative program. Many states feel that the NCHRP and the research performed by other states preclude the need for extensive internal research programs.

A number of states have tried different techniques for developing research programs. Some have canvassed operating personnel for suggestions for research topics. This has not been satisfactory in some states for the following reasons:

1. Much of the information requested by operating personnel has already been researched and needs only to be identified and made available to them;
2. The questions raised are not researchable;
3. The research required to resolve the issue is beyond the capability of the staff, or sufficient funds are not available to conduct it. The best assurance of a sound research program is a close communication between operating personnel and researchers, and some states have formal mechanisms to insure this.

The content of research proposals varies among states. In some states research proposals are very concise, and in others they are very elaborate. In some states project approval is left to the research administrators; in others research projects must be approved by the highway commission. In general, research proposals submitted in-house are less comprehensive than those for contract research.

Some states endorse the concept of providing highway research funds for underwriting graduate student education; for example, the joint cooperative program at Purdue University is used totally for support of graduate student research. In other states there is a growing reluctance to support student research with highway funds.

One of the problems that almost every state encounters is the reporting of research and the translation of research into practice. The highway community is concerned by the fact that states are not taking advantage of research findings. Printed reports are generally the primary mode for the communication of research. A number of states use committee meetings and conferences to communicate research findings. Little is being done at the present time by the states to use other media for translating research into practice.

The recruitment and retention of research staffs has been one of the limiting factors in the development of in-house research programs. The states that have their research units located near universities and use part-time student help rely heavily on recruitment of university graduates for research staffs. With such a staff, however, there is often considerable turnover. Some states have found it profitable to recruit researchers from field personnel. However, in some states research is viewed as a dead-end for career progression, and many of those who do enter the field find research too slow a pace. Some states have set up special classification systems for researchers, in an attempt to make them competitive with academic positions. Other states have integrated research with the career ladder of other highway positions and recruit personnel by competitive testing and certification.

These are some of the factors involved in the development and operation of highway research programs. As state highway programs broaden their horizons toward intermodal activities, research activities undoubtedly will broaden also. The past few years have seen substantial growth in planning research, as well as physical and engineering research. There are indications that highway research needs are in a state of transition and that, in addition to traditional highway research programs, greater emphasis will be given to social, economic, and ecological research related to planning total transportation sys-

tems. As these new programs develop, there will undoubtedly be a reevaluation of current highway research programs and organizations to accomplish the new goals and objectives.

Case Studies of State Highway Research Programs and Research Institutes

CALIFORNIA

California is currently allocating \$8.5 million for planning and research activities, of which approximately \$3 million is for the Division of Highway's formal research program. About \$5 million of this total is Federal-aid 1½ percent funds. Of the remaining \$3.5 million, \$1 million is necessary state-matching funds, and \$2.5 million is purely state funds.

California has the largest in-house research program of all the states. The philosophy of the Division of Highways is to do as much of the research within the division as possible. Only those problems for which it does not have the necessary personnel, talent, or equipment to solve are performed by contractors. The research program receives endorsement by highway management because it is strongly oriented to highway problems. Almost all of the research program is in response to operating problems of the division.

The highway research program is under the review of the Research committee. Administratively, the program is the responsibility of the assistant state highway engineer for planning, who has delegated administrative authority to the Urban Planning department. The research committee, which is composed of the five assistant state highway engineers and the right-of-way agent, has approved a continuing five-year research program. The research program is based on projects recommended by each of the department heads and by the district engineers. Each year the five-year program is reviewed and updated and new projects are added. Like many other states, because of the additional use of the Federal-aid funds for urban transportation studies, there are not sufficient funds to finance all proposed projects. The research committee has recommended that the research budget be increased 10 percent per year beginning in the next fiscal year.

Since it is oriented toward problem-solving, the research program has a high rate of payoff. Whereas some other states use their HPR funds for supporting student research at universities and for underwriting basic research projects, the California Division of Highways, both for in-house and contract research, is primarily interested in resolving current construction and operations problems. An annual report of savings as a result of research is prepared and submitted to the state highway engineer. There are currently about 200 active research projects under the research program. The largest department performing research is the Materials and Research department, with a current research budget of over \$1 million a year. The Bridge, Traffic, and Right-of-Way departments also perform large portions of the division's continuing research program. There are also several research projects being conducted by the highway districts.

In addition to highway and Federal-aid funds expended for research within the Division of Highways, the legislature has been appropriating \$250 thousand annually for safety research. Each project is approved by the Transportation Research Council. The Council is directed by the Business and Transportation Agency and includes the Division of Highways, Department of Highway Patrol, Department of Motor Vehicles, and the University of California Institute of

Transportation and Traffic Engineering. Agencies and universities interested in performing safety research make proposals to this committee for funds.

California integrates daily operations and research under the same administrative structure. Staff members with the inclination and talent for research may be designated to perform a specific research project within an operating unit. One of the drawbacks in this arrangement, however, is that when there is a shortage of personnel or when the routine workload becomes excessive, the research suffers accordingly.

Approximately 25 percent of the California highway research program is under contract arrangement. Most contract research is performed by the University of California either at Berkeley or Los Angeles. Most of the research done under contract is in the area of traffic and safety. Projects with the university are on an individual project basis, and there is no continuing level of support. Although there is a long-term master agreement and standardized contract with the University of California, a supplemental research technical agreement is drawn up for each project. The operating or staff unit within the division that is most interested or closely associated with the research project under contract is designated to monitor and review the project.

There has not been extensive pressure from the state and private universities for contract research because the type of research desired by the Division of Highways is problem-solving rather than basic research. Such research does not lend itself readily to use as instructional or thesis research. The legislature has also created and funded the University of California Institute of Transportation and Traffic Engineering with branches at Berkeley and Los Angeles.

All research projects are coordinated through the assistant state highway engineer for planning. Each year all the headquarters departments and the districts are requested to submit their long-term research needs. These are considered by the staff in preparing a proposed five-year research program. By informal contacts between the Urban Planning department and the various headquarters departments, many of the initial proposals are filtered out as problems having been resolved, with information available to the requester; as problems already being researched; or as problems that cannot be readily solved within the limitations of the state's research program. Less than 10 percent of the problems referred to the committee from the districts result in research projects. About 50 percent of the research proposals come down from management (usually staff and operating divisions) and about 50 percent come up from research personnel. All proposals must be evaluated and administratively approved before any research projects are initiated. Though operating personnel are not always a good source for research problems, California has found that the request for problems has provided multiple benefits. It has produced a beneficial public relations effect and has opened up another communications channel for discussing operational problems. Operating and engineering personnel are more amenable to accepting research findings when they are asked to cooperate in making their problem-solving research needs known.

Because funds are directly allocated to municipalities, a number of state highway departments are not responsible for the construction and maintenance of urban highways. Other states, though responsible for the construction of Federal-aid urban highways, are not responsible for their maintenance once completed. In California, the state maintains its freeways in urban areas, but in many cases delegates maintenance of the conventional state highways to the cities. The state pays the cities for such maintenance under individual maintenance agreements. California has been extremely interested in urban highway and traffic problems. Both the Traffic and Right-of-Way departments have continuing research programs on the effects of freeways on the urban environment.

Each staff or operating department having a continuing research program includes in its budget a request for sufficient funds to continue the costs of its research unit. The division research program is based on the availability of funds and the relative priorities of individual projects. Each department is allowed a limited amount of funds for research, based on its capacity to perform it and the relative priorities of the proposed projects. In this way an on-going research program may be developed in the operating units.

Project cost controls are used to assist in the monitoring of each project. By keeping track of the rates of expenditure, those responsible for administering the research program can determine the amount of activity on each project. The performance of each project is continually evaluated by a review of reports, the monthly rate of project expenditures, and informal discussions with research personnel. The state has a flexible procedure for terminating research projects; for example, when the research administrators believe that a project is no longer productive or is not receiving the proper attention, they informally suggest to the responsible department that it request approval to discontinue the project.

The departments have the freedom and the responsibility to allocate their research personnel and equipment (thus determining the project size) within certain overall administrative constraints. Except where considerable equipment or materials are required, the typical project costs are about \$20,000 per year.

At the present time, it is the responsibility of each of the assistant state highway engineers and the chief right-of-way agent to disseminate and implement the findings of the research projects under his supervision. There has been no centralized system for the reporting of research findings, but there is such a system for reporting the results of implementations of the findings. A move is currently under way to develop a more formalized system of reporting that will insure a wider distribution of research reports and further disseminate the findings.

The recruitment and retention of research staff is a key to the California highway research program. California relies heavily on the use of operating engineering personnel and technicians as a source of research personnel. In contrast to university research, which tends to be research oriented, the California program is problem oriented in that efforts are directed toward finding answers rather than developing new knowledge. Under this type of program, researchers with practical rather than theoretical orientations are needed. Rather than locating the research unit on a university campus and depending heavily on faculty and graduate students to perform research, California has found it more feasible to locate the research units within operating divisions and to use operating personnel with a penchant for research to perform the projects.

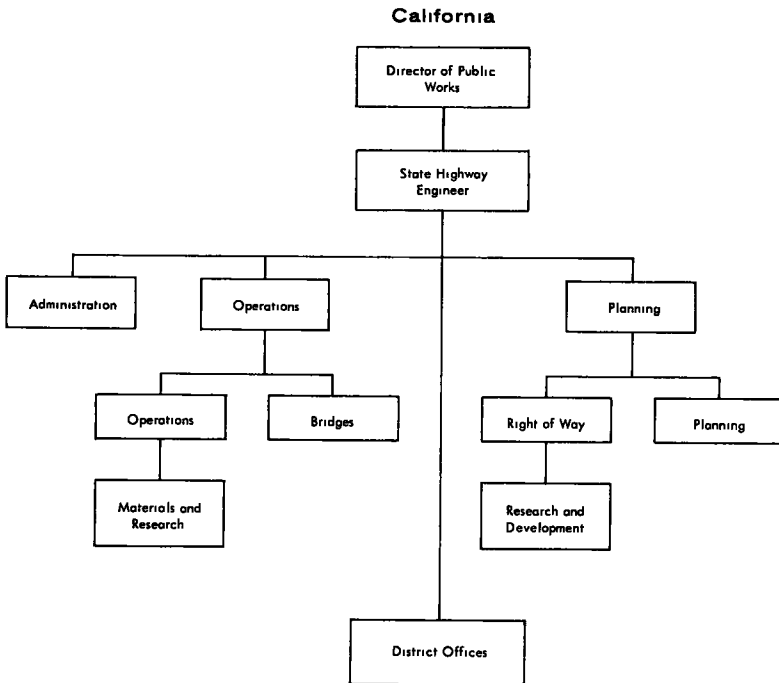
The Materials and Research department employs about half of the researchers in the state program. Staff is obtained primarily by transfers from the operating divisions. Few researchers at the higher levels are recruited from universities. The research staff classification systems are integrated with the overall highway classification system. No special educational requirement is necessary for the research staff, and premium salaries are not paid. However, there has been some recognition of the technical qualifications of researchers in that less emphasis is placed on the number of persons supervised for qualification to the associate and senior research engineering levels. To qualify for senior level positions engineers must have a professional engineering license. Many of the associate-level engineers are already licensed. Qualified individuals with needed specialized talents in research areas ex-

perience little difficulty in obtaining advancement. The Materials and Research department has had little personnel turnover at the senior research levels, but there is considerable turnover at the junior and assistant engineer level.

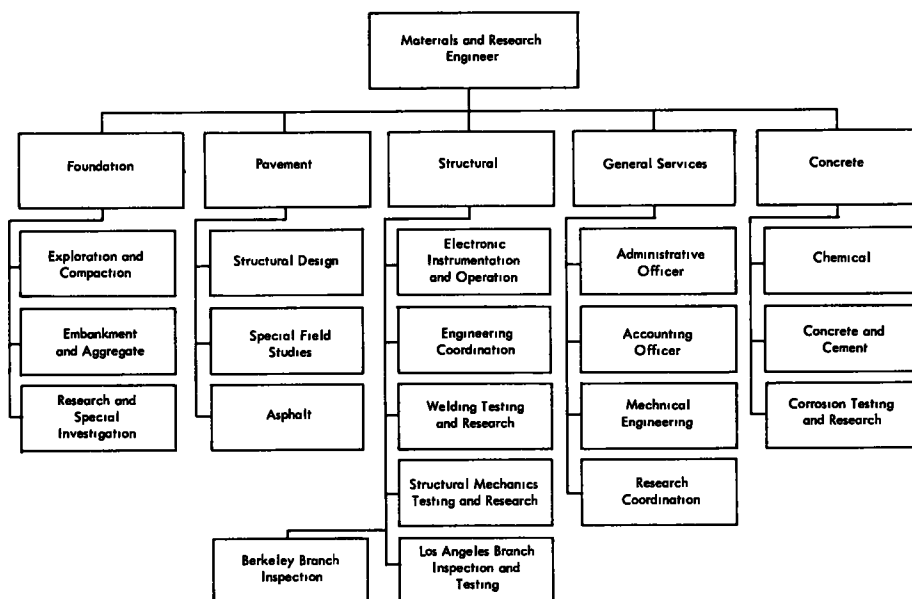
California's position classification system is based on a stratified level of engineering proficiency rather than on specific position descriptions. Most engineering positions in the Division of Highways are classified into five levels: junior, assistant, associate, senior, and supervising engineer. The tests and the experience and educational requirements for these levels are generally the same regardless of where the position is located. The position requirements cover all phases of engineering rather than a specialized area. However, there are a few specialized positions in research. Above the assistant engineer level, promotion is by written and oral examination. Junior engineers are on a rotation program that helps provide them with a background of broad experience. In order for a young engineer to progress he needs to gain as broad a background of experience as possible, since the tests cover all phases of engineering. Therefore, at the lower level there has been high mobility among young engineers within the Division of Highways. Those who have met the qualifications and have passed the tests for the next level of promotion may apply for any open positions throughout the Division of Highways either within the districts or within the central office staff functions.

The emphasis within the division continues to be on operating activities. When there are limitations of funds or personnel, the research program suffers. For example, a highly qualified operating engineer may often be diverted from a research project to line operating responsibilities in periods of heavy workloads.

Most of the research is done by the Materials and Research, Bridge, Right-of-Way, and the Traffic departments. It has been difficult for the smaller departments to find researchers who can be utilized on a full-time basis.



California—Material and Research



INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING UNIVERSITY OF CALIFORNIA

The Institute of Transportation and Traffic Engineering at the University of California was established as a result of state legislation in 1947. This legislation provided for initial funding and indicated that the purpose of the Institute was to carry on instruction and research concerning all modes of transportation, including traffic safety. The Institute maintains staff and facilities at the Berkeley and Los Angeles campuses of the University's Richmond field station. It conducts varied programs of research, supports graduate education in transportation engineering, and develops a continuing and statewide program of extension courses.

The activities of the Institute are administered by a director and two associate directors, one at Berkeley and one at Los Angeles. These officers, together with the deans of Engineering at the two campuses, form an executive committee that establishes general guidelines for long-range development. An advisory committee, appointed by the president of the university, periodically reviews institute activities; this committee includes members representing city, state, and Federal agencies, service organizations, industrial concerns, and various university departments.

The Institute's programs are currently at the level of about \$2 million a year, about half of the research being conducted at Berkeley and half at Los Angeles. Areas of attention are broadly classified as follows:

- Transportation theory, systems analysis, and operations research;
- Transportation economics and administration, and systems planning;
- Highway planning, design, and traffic engineering;
- Air transport planning, design, and operations;
- Materials and structures;
- Vehicles, equipment, illumination, and sound; and
- Human factors.

Human factors research and research concerning full-scale vehicle collision experiments and driving simulation are concentrated at Los Angeles, while most of the work concerning air transport and materials and structures is concentrated at Berkeley. At both locations, more than half the current activity is in programs directly concerned with highway and traffic safety.

At Berkeley, the regular staff consists of about 25 professionals and 35 supporting personnel. Nearly all of the professional staff members also hold academic appointments in the department of Transportation Engineering and devote part of their time to teaching. At Los Angeles, the permanent staff consists of about 20 professionals and 35 supporting personnel. Some of the professional staff also hold teaching appointments, and graduate students work as research assistants.

There is a considerable amount of unsponsored faculty research, and substantial contributions from graduate students, many of whom undertake individual or group research projects as part of their educational programs. Contract research is conducted for a variety of organizations, the larger present contracts being with the Federal Highway Safety Bureau, the Federal Aviation Agency, the California Highway Patrol, the California Division of Highways, and the California Department of Water Resources.

Institute support of graduate study at Berkeley led to the establishment of a Division of Transportation Engineering in the College of Engineering and to a large, diversified graduate program currently enrolling some 150 students. Half of these are in the general transportation engineering field and half in the geotechnical engineering field, which includes soils mechanics and pavement design.

The Institute supports advanced study at Los Angeles through guidance of students engaged in research, through the provision of extensive research facilities, and by providing employment on Institute research projects. In addition, under a grant from the U. S. Public Health Service, the Institute offers 24 predoctoral research traineeships in accident causation.

Among its statewide activities, the Institute conducts an extension education program in cooperation with the University of California Extension, enrolling some 3,000 students per year. The emphasis is on special short courses and seminars. A senior staff member devotes full time to the extension program.

ILLINOIS

Within the Illinois Division of Highways, the Bureau of Research and Development is responsible for the administration of the research program. Duties of the bureau include the development of background information necessary in the selection of the research program, the arrangements for financing the program, performance of assigned research, coordination of studies assigned to others, and the practical application of findings of the research. Between 40 and 50 projects are active at any one time.

The Bureau of Research and Development is the principal internal research agency for the Division of Highways, and it also administers and coordinates research sponsored at such educational institutions as the University of Illinois and Northwestern University. The Bureau of Planning conducts several planning research studies and is responsible for the division's activities related to the Chicago Area Transportation Study (CATS). Some of the operating divisions occasionally conduct investigational and demonstration-type projects. For example, the Bureau of Design has developed a safety demonstration project and the Bureau of Right of Way has studied problems of appraisals and right-of-way acquisitions.

Research and development activities are separated from the routine material testing functions and are among the responsibilities of the deputy chief highway engineer for planning. Highway research in Illinois was once primarily physical research but has now broadened substantially to include planning, traffic, economic, and similar types of research.

The Bureau of Research and Development operates within a framework that includes a structural research section, a research coordination unit, a products evaluation unit, an instrumentation development unit, and an expressway surveillance research unit. The structural research section is subdivided into a pavement research unit, a bridge research unit, and a foundation research unit. The pavement research unit is concerned primarily with field studies of pavement performance. A current important assignment of this group is a study of the rehabilitated AASHO Road Test facility. The bridge research unit is concerned mainly with field studies of bridge performance. Much of its work involves the extension into the field of theoretical research conducted in the structural laboratories of the University of Illinois. The foundation research unit is concerned with pavement and bridge soil support studies. The research coordination unit is responsible for all of the contract research projects that are sponsored by the Division of Highways at the University of Illinois and elsewhere. The products evaluation unit evaluates the new products and processes that are continually coming on the market for use in the highway field. The instrumentation development unit is a support group that provides most of the specialized instruments and devices used on the research and development projects. The expressway surveillance unit is a special group operating in the Chicago area with the objectives of finding ways to reduce congestion on urban expressways and of finding a means of fast communication that will help stranded or injured motorists.

Two advisory councils assist in the research and development program. The Illinois Highway Research Council is a 13-member group serving in an advisory capacity to the chief highway engineer in matters of research. Council members represent the Illinois Division of Highways, the U. S. Bureau of Public Roads,

the county superintendents of highways, the city engineers, and engineering educational institutions of Illinois. It reviews work on active research projects, reviews reports of work completed, makes recommendations concerning projects suggested for addition to the research program, and suggests practical applications for the results of research. Two regularly scheduled meetings are held each year, with special sessions as necessary. At one meeting, research activities of the Bureau of Research and Development are reviewed and new proposals are considered. The other meeting is devoted mainly to the cooperative research program. At both meetings, researchers report on their progress and on the research program for the next fiscal year. Between five and ten research proposals are reviewed by the Research Council each year. The research coordination unit acts as a secretariat to the Research Council.

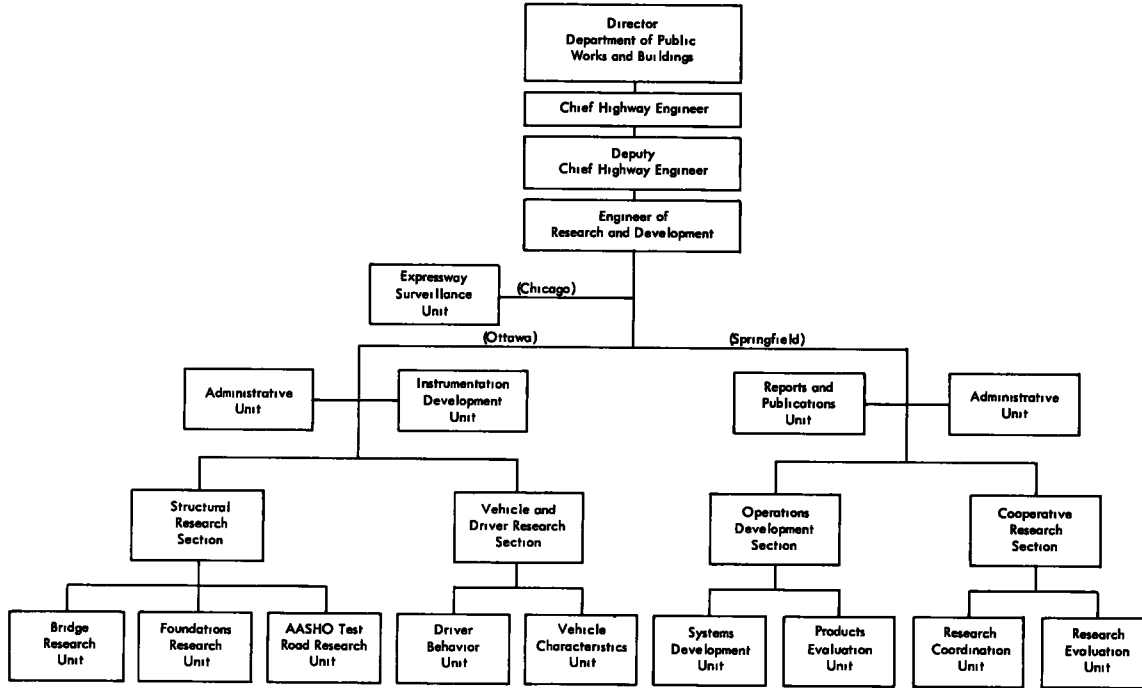
The Illinois Highway Development Council is an eight-member group composed of principal members of the Division of Highways serving in an advisory capacity to the chief highway engineer in developmental matters. This group reviews and makes recommendations relative to practical applications in the highway field of new products, new materials, and new processes. During fiscal year 1966, seventy-two proposals for new products, materials, and processes were received by the Bureau of Research and Development. Thirty were found to be of sufficient importance to warrant review by the Development Council, eight of which were recommended for adoption and four for use in trial installations. The product evaluation unit serves as a secretariat to the Development Council.

A project advisory committee is assigned to each research project of the Division of Highways. Committee membership is based on interest and specialized knowledge. Two members of each advisory committee are from the division (one from the bureau most directly affected by the project and one from a district); two are from the organization performing the research, if it is a cooperative project; and one is from the Bureau of Public Roads, if it is a Federal participating project. The engineer of research and development is also a member. The project supervisor acts as the chairman and the project investigator as the secretary, with neither having a vote. The committees meet at least once a year to advise the research staff and to evaluate progress. Committee members are expected to play a major role in getting research findings adopted into practice. Research reports from the cooperative program usually are published by the agencies doing the research work.

The Bureau of Research and Development has a staff of approximately 80, and an annual budget of about \$1,500,000. There are 58 full-time and 22 part-time employees. The cooperative research program at the University of Illinois currently has a budget of approximately \$350 thousand a year. The sponsorship of highway research by the Division of Highways at the University began in 1936 but was not placed on a continuing basis until 1951, at which time a basic contract for a continuing program of research was initiated. There are 25 projects on the cooperative program at the present time. About five new projects are proposed each year. New projects are initiated by the addition of individual supplemental agreements to the basic contract.

Even prior to the 1962 Federal Aid Act requiring urban transportation planning, the problems of transportation in the Chicago area had developed to the extent that a cooperative arrangement was created between Chicago, Cook County, and the state, to study the problems of urban transportation and to develop a master road and street plan for the Chicago metropolitan area. A policy committee representing Chicago, Cook and DuPage Counties, the Bureau of Public Roads, and the state of Illinois, was created to supervise and review the conduct of the study. The Chicago Area Transportation Study has the re-

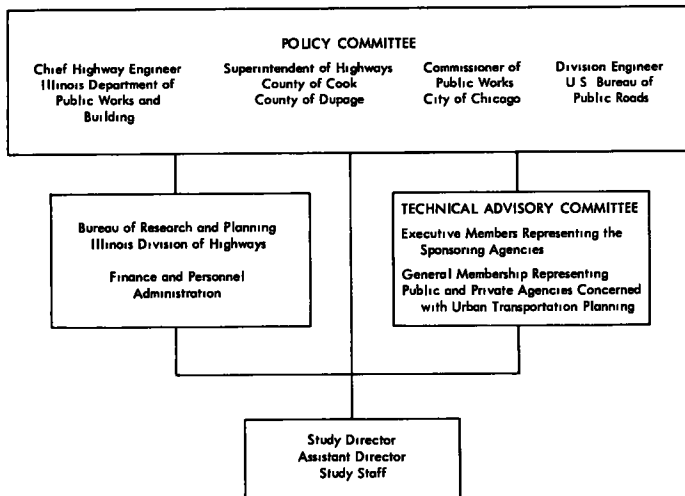
Illinois—Bureau of Research and Development



sponsibility for servicing the needs of supporting agencies, conducting transportation research, and maintaining and updating factual inventories. The Illinois Division of Highways provides the personnel for the CATS staff. The majority of the program is financed from HPR Federal matching funds. The city of Chicago and the counties provide 12 percent of the total cost. The study is directed by the policy committee, which meets every three months and reviews the activity of the study staff. For the current fiscal year almost \$750 thousand in state and Federal-aid funds is allocated to this study. Although much of the activity of the transportation study is of a recurring, nonresearch nature, the organization does conduct a significant amount of research.

When planning research activities are considered together with other research activities, the total annual research program of the Illinois Division of Highways is over \$2 million.

Chicago Area Transportation Study Committee Structure



INDIANA

Indiana pioneered in highway research. As early as 1920, research for the Highway Department was being done at the Purdue School of Engineering. The

legislature enacted a one-line law in 1936 allowing the Highway Commission to allocate funds to Purdue for research, road schools, and extension work. With the enactment of this law the Joint Highway Research Project between Purdue and the Indiana Highway Department was created. Currently, approximately \$500 thousand dollars is budgeted annually for the Joint Highway Research Program. Of this, \$320 thousand is financed under the Federal-aid HPR program. These funds are allocated for specific projects for which working plans have been prepared and approved by the Indiana State Highway Commission and the Bureau of Public Roads. An additional \$200 thousand of state funds is directly apportioned to the joint project by the Highway Department in the form of a grant. These funds are used by Purdue for highway research, road schools, or extension, at its discretion with approval of the Joint Highway Research Project Advisory Board. While the Federal-aid funded research program is tied directly to projects, the \$200 thousand of state funds is not directly tied to specific projects and is used to guarantee a continuing research program.

Unlike highway research at many other universities, only a small portion of the funds apportioned for the Joint Highway Research Project is used in support of faculty research. Almost all of the funds are used to support graduate student research. About 50 graduate students are receiving stipends through the Joint Highway Research Project. About half are working toward masters degrees and half toward doctoral degrees. Fifteen are graduate students in transportation materials. The remainder are enrolled under transportation and urban engineering.

Under the assistantship program, graduate students receive payment plus tuition and fees for 20 hours of work a week on a research project that provides them with material for their theses and that is financed through the Joint Highway Research Project. The students are allowed to carry a 12-hour course load and work half-time on their theses. There are also a few full-time student employees who work one-half time on their theses research and one-half time on other research or teaching responsibilities. However, these students may take only six hours of course work per semester.

The graduate students are allowed to select their own theses projects. Therefore, the research of the Joint Highway Research Project is dependent on the interest of the students enrolled in the program. However, most of the graduate students do not have fixed ideas about a thesis topic, and the faculty guides them to projects that are of interest to the Indiana Highway Department and the Department of Civil Engineering. Research topics are suggested by the Highway Department and by the faculty.

There is no formal contract between the Highway Department and the university as there is in other states. The Joint Highway Research Project is handled by unwritten mutual agreement between the two parties based on the enabling statutes. Suggested research topics are communicated by memorandum or personal contact between Highway Department officials and the university faculty.

Since the university uses the Joint Highway Research Project primarily for support of its graduate training program, the theses projects conducted under the program are directed at basic as well as applied research. It is the university's philosophy that research should be oriented to the educational program rather than stand as a separate entity.

However, there are a number of proposed projects by the Highway Department that are not of thesis research quality. These are assigned as studies to students who are not in the process of writing their theses, or who have not yet decided upon a research topic. Generally such projects are of limited

scope and for a limited time. Since some Highway Department requests for research must wait for interest of a graduate student, it may take a number of years to accomplish a desired project. This was one of the reasons for the creation of the Highway Department's new Research and Training Center, which is staffed with highway personnel who can give immediate attention to solving emergency problems.

The half-million dollar budget for the Joint Highway Research Project does not include any overhead charges by the university. Whereas the university charges an overhead rate of over 50 percent of salaries on other research contracts, overhead charges under the joint project are absorbed by the university. Faculty members supervise graduate students performing research under the project as part of their normal academic duties. Research responsibilities under the project are offset for faculty members by a reduction in teaching and other assignments. It is the policy of the university not to have its faculty devote full time to research. Because some industrial and governmental contracts, such as those of the NCHRP, require full-time efforts of one or several researchers and provide a limited period for the production of a report, the university is not interested in this type of research. It also believes that it would be inappropriate for its faculty or students to perform research related to the evaluation of the Indiana Highway Department operations.

Because research is tailored to thesis requirements of graduate students, the size of projects is often limited. The length of individual phases of a project is governed by the length of stay of the graduate student involved in the research. However, there is an attempt to develop large projects that use a number of graduate students working on different phases.

The Highway Department has a bureau of materials and tests, located in Indianapolis. It is staffed with Highway Department employees and is concerned with materials testing and some applied research. However, the Interstate program has required the expansion of testing activities and research activities have been diminished. Over the years it has become evident that the use of operating agencies to perform applied research has not provided an adequate solution. Since the Joint Highway Research Project is primarily oriented to basic research there is a need within the department for a faculty that can do additional applied research. There is a need to translate the theoretical research developed under the Joint Highway Research Project into specifications and procedures that can be used by the Highway Department. There is also a need for a centralized training center for the development of subprofessional and professional highway employees. Through the efforts of the Joint Project faculty and Highway Department personnel, a new Research and Training Center located at the Purdue Industrial Park has been created to accomplish these objectives. The new center has a number of training programs primarily for subprofessional highway employees.

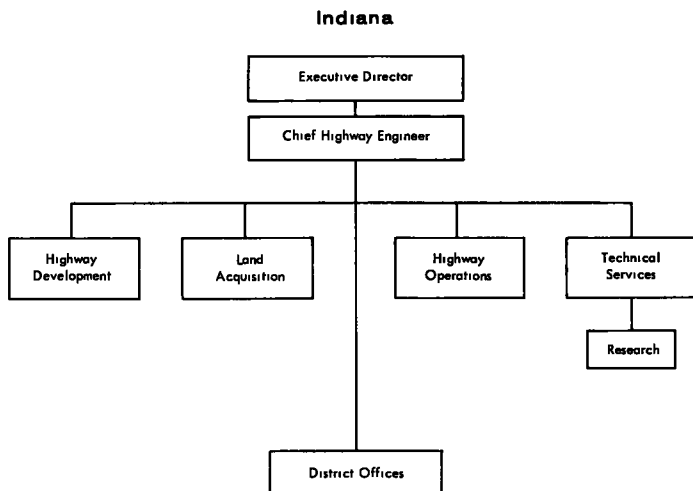
The research center is intended to centralize all research activities of the Department in one place. However, several of the researchers within the Highway Department operating divisions have not been willing to make the change to the new location, so research (at least for the time being) will be done both by the research center and the operating units. One of the problems of obtaining research personnel is that salary levels are controlled by the state personnel classification system rather than by the academic and engineering research marketplace, which is the primary source of researchers. One of the inducements being used to attract researchers to the center is the opportunity to obtain advanced degrees at Purdue while working for the research center. Students interested in this arrangement are often older students with families that could not subsist on the income provided by an assistantship program.

The primary responsibility for research administration lies with the Office of Technical Services in the Highway Department. It also acts as liaison between the faculty of the Joint Highway Research Project, the Highway Department, and the Bureau of Public Roads. Two committees are responsible for monitoring and reviewing research. A Joint Highway Research Project advisory board monitors the research program at Purdue. This committee is composed of the six members from the Highway Department and six members from Purdue University. It meets eight times a year to review research progress and proposals. Graduate students report on their research before the committee. The board also reviews and recommends the following year's research program budget.

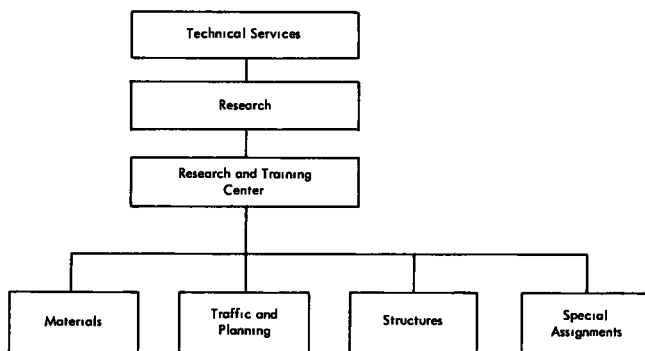
A research committee was established by the Highway Department in 1964 to review the overall research activities of the department and to make recommendations to the executive director regarding research and the allocation of funds and manpower for projects. The committee meets quarterly to review research in progress in the operating agencies, at the new research center, and at Purdue. It also reviews contract research let to agencies and universities other than Purdue.

As in other states, the responsibility for physical research is located separately from planning research. Physical research is the responsibility of the Office of Technical Services, while planning research is under the Office of Highway Development. There is no formal planning research organization, and research is done by individual staff members.

Keeping highway administrators and engineers informed of current research findings is a universal problem in highway research. One way that Purdue attempts to bridge this gap is by devoting a session at their annual road school to recent research findings. (The road school is financed from the state funds allocated under the Joint Highway Research Project.)



**Indiana Highway Department
Research and Training Center**



IOWA

The Iowa Highway Department is a strongly centralized organization with an active highway commission. There are five highway commissioners and an administrative secretary, who is also chief administrator of the department.

The research activities in the state are located under the Division of Planning. The Research department is an administrative organization responsible for the supervision of research conducted within the department and under contract. There is no separate research organization or facility within the department itself. In-house research is conducted by the operating departments or by the Materials department, which has a separate special problems section, with a staff of seven to perform the in-house research. Although the section is part of the Materials department, if a research project is done under the auspices of the Iowa Highway Research Board, the administration of funds and publication of reports is the responsibility of the Research department.

The Research department was created in 1949 by order of the chief highway engineer. It is supported with Federal-aid HPR funds, state primary road funds, and 1½ percent of Federal and state funds allocated for farm-to-market roads. A highway research board was created to prepare and supervise the research program. There are 13 members of the board who are appointed by the state highway commissioner and serve staggered three-year terms. At present, there are six county engineers, two city engineers, three representatives from the Highway Department and two members from the state universities. The research engineer serves as secretary to the board. The number of county engineers is due to the allocation of secondary road funds for research and, because of this representation, counties show considerable interest in the research program. The Highway Commission receives recommendations for appointments to the Iowa Board from agencies such as the County Engineers' Association, the League of Iowa Municipalities, and from the

universities. The board meets monthly to review research proposals and progress reports, and to approve completed projects.

Most suggestions for projects originate from the Materials department and from county engineers. The universities prepare their own proposals and submit them through the Research department to the board. Suggested research subjects are sent to the department for review and approval by the Iowa Highway Research Board. The general procedure is for the topic to be proposed along with an estimated cost. The research board examines each individual research proposal. If the board recommends the proposal, then a very brief statement of the proposed research is given to the commission with a request to obligate the required funds. Recommendations are not forwarded from the board to the commission unless funds are available in the current budget. When a project has been approved for research, its priority depends upon the availability of staff or contractor.

The functions of the Research department are to obtain funds for projects, develop detailed working plans for in-house projects, administer funds for research projects, and act as secretary to the board.

The research program expenditures for fiscal 1967 are estimated to be \$206 thousand. Approximately 50 percent of the total research expenditure is for contracts with Iowa State University and the University of Iowa. Research done within the state highway department amounts to \$100 thousand.

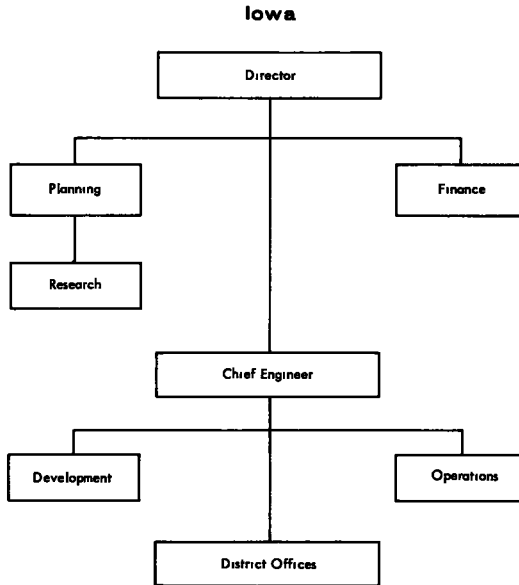
The average project requires about three years to complete, with an average cost of \$10 thousand to \$15 thousand a year. Of the 21, only one is financed with Federal-aid 1½ percent funds. If a contract research project requires more than one year to complete, a yearly progress report is made. There are no formal methods for reporting on the status of projects at the monthly meeting of the Iowa board.

In addition to the research administered by the Research department, planning research is also conducted by other sections of the Division of Planning. In the past, almost all of the department's program has been in physical research. However, Planning is presently being asked to conduct research on such topics as economic impact of highways. Consultants are sometimes employed for specific studies not appropriate for university research and beyond the scope of the Highway Department. A uniform cost accounting system and a programmed teaching system were recently completed by such consultants.

Research staffing is a problem in Iowa. Although the salary structure is good by highway department standards, it is not comparable to academic standards. Recruiting people from operating divisions has not proved successful, because research does not seem to provide the same sense of accomplishment as construction or other highway operations. Because of the general feeling within the highway department that research may be a dead-end with little opportunity for advancement, the department tends to rely increasingly on contract research for its needs.

Contracts with Iowa State University's Department of Civil Engineering are on an individual basis and are often used as a source of funds for graduate assistantships. In previous years each university department made its own contracts with the highway department. Currently, all research funds have been centrally controlled and administered by the university's Research Institute. There has been a shifting of interest in students at the universities away from materials research and toward traffic research. Therefore, it has become increasingly difficult to obtain laboratory assistance. Most of the graduate students recruited under the assistance program are citizens of other countries studying at the university.

There is no extensive pressure for payoff of projects at the present time. As with other states, one of the problems has been that there is no formal way of translating research done at the universities into actual practice.



KENTUCKY

Kentucky allocates more than \$400,000 per year for highway research. In 1941 the Highway Department set up a separate highway research laboratory on the campus of the University of Kentucky, staffed with Highway Department employees. Until 1949, research was a branch of the Division of Design. Since then, research has been established as a separate research division. The Division of Research is headed by a director and an assistant director. The physical research laboratory is divided into sections, among them concrete pavement and structure, bituminous paving materials, soils and foundations, surveys and exploration, engineering mechanics, and pavement surface characteristics sections. In addition to these sections, which are located at the laboratory, the Division of Research is responsible for traffic and safety research, economics, right of way, and other nonphysical research.

The Research division has directed its primary efforts toward solving specific problems of the Highway Department. The primary emphasis of re-

search has been physical research, although research contracts have been let for economic, financial, and administrative studies. The research program has had a high rate of acceptance by highway engineers and administrators because of its orientation to solving highway problems.

Although the research laboratory is located at the University of Kentucky and the Department of Civil Engineering and the Research Division maintain cordial relations, there has not been the extensive use of faculty for highway research as there has been in other states, such as Indiana. The Research division endorses the concepts of staff teaching assignments, the development of short courses, and informal student assistantships as a legitimate part of the highway research program as long as it does not interfere with the primary research function of the division. The chief research engineers and research administrators teach one course per year at the university. The division feels that a greater teaching load would detract from its research efforts.

While the research laboratory does not have a formal graduate assistantship program, it hires part-time undergraduate and graduate students and, wherever possible, tries to have the graduate student work on a research project that also can be used for a thesis topic in the School of Engineering.

Projects are suggested by highway engineers, administrators and researchers. The majority of the projects, however, are suggested by Highway Department engineers as a result of problems they encounter. Project proposals are reviewed and endorsed by the principal research administrator. The department has established a research committee to review the research program and to serve as a means of putting research findings into practice. This committee suggests priorities for research projects and, because of its composition, is an excellent source for getting highway management to endorse and utilize research findings. Another means for translating research findings into practice is through follow-up reports.

All research within the Highway Department, other than research involved in the planning functions, is coordinated through the state highway engineer. Under the current program there are few projects that are not being done by the Research division laboratory.

Financing the research program has not been a problem in Kentucky. Until 1962, the Highway Department financed it with 100 percent state funds. Because of the dedication of HPR funds for planning and research purposes under the Federal Highway Act of 1962, the research program is now being financed with Federal-aid matching funds. The current budgetary controls comply with those required by the Bureau of Public Roads. However, there is no pressure for tight program cost controls. Most projects are of a continuing nature and may last three or four years. Annual progress reports are reviewed with Bureau of Public Roads officials. The funding of the Research division, while on a project-by-project basis to satisfy HPR requirements, is sufficient to guarantee a continuing research program, and should there be any problems with Federal-aid funding the Highway Department would supply necessary 100 percent state funds to continue the research program at the desired level.

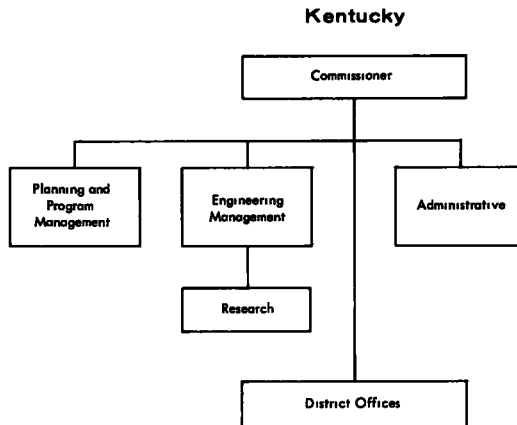
As part of its function the Research division does a limited amount of new product evaluation for the Highway Department. There is no new product evaluation committee; product evaluation is limited to problem areas where specific needs exist.

A continuing problem in the Kentucky research program is obtaining the staff to perform all the desired projects. Like other research units closely affiliated with universities, the primary source of permanent staff has been through graduates from the university who have either worked for the research laboratory or for the Highway Department before graduation. All of the present

research staff came to the department through the university. There are 20 full-time researchers and 25 students, both graduates and undergraduates, working at the research laboratory. A number of the research staff are working on advanced degrees at the university and at the same time working full-time for the Highway Department. Most of the part-time engineering student helpers are in the field of materials.

In addition to the research facilities providing part-time work for students at the University of Kentucky, the Highway Department established a scholarship program with the university in 1948. Scholarships are currently available for 30 freshmen, 20 sophomores, 15 juniors, and 10 seniors. Any resident of Kentucky who has graduated from a Kentucky high school and who is enrolled in the School of Engineering at the university is eligible. Under this scholarship program the student works during the summer as an engineer's helper for the Highway Department and during the year receives a fixed stipend depending on academic status. The student is required to pay all tuition and fees to the university. In return for the scholarship, the student is obligated to remain in the employment of the Highway Department one year for every year he was enrolled in the program. The scholarship program is directed through the university and is not part of the research program.

Research findings are printed in formal reports to the department; those having general interest and application may be offered for publication.



LOUISIANA

In 1965, highway research in Louisiana underwent a major reorganization. Until that time research activities were combined with the testing functions.

In July 1965, research was set up as a separate section. The research laboratory is located on the campus of Louisiana State University. The staff numbers 79 people, of whom 14 are engineers, 6 are geologists, 39 are technicians, 8 are clerical staff, and 14 are part-time students.

The Highway Department's research program is financed from 50 percent of the Federal-aid 1½ percent HPR funds. Over \$1 million is programmed for highway research, of which \$600 thousand is utilized for in-house research and over \$450 thousand is allocated for contract research. A Research Advisory Council, composed of construction, maintenance, material, planning, and other engineering interests of the Highway Department; representatives of the Bureau of Public Roads; and representatives from the state universities, meets about twice a year to review the program.

In addition to the Research Advisory Council, project advisory committees have been established to assist in the detailed planning and review of research proposals. There are four members on each one of the project advisory committees, three from within the Highway Department, and one from the Bureau of Public Roads. The function of these committees is to assist in the development of the project and the dissemination of research findings. For projects assigned to outside agencies, a technical coordinator, who is a department engineer, is appointed to act as liaison between the principal investigator and the Highway Department on matters relating to the study. The technical coordinator is frequently assigned from the staff of the Research station.

When the Research and Development section was separated from the testing functions, it was made directly responsible to the assistant chief engineer. The program has been mostly applied physical research both in the Research section and research contracts.

Proposals by the universities for research are developed from three sources: from the research staff, from a list of research needs prepared by the Highway Department, and from proposals from the universities. About 40 percent of the proposals submitted by the universities are accepted. The list of needed research is prepared by a special projects committee every two years.

The staff of the Research section makes recommendations regarding research proposals to be submitted to the Advisory Research Council. In about 80 percent of the cases the council accepts the recommendations of the staff. About half of the proposals for contract research originate at the university, and half are the result of suggestions made by the Research section regarding needed research. In 1961, a canvass of the Highway Department was made for possible research projects. There was a generally poor response and the Research section has found that personal contacts with department engineers are much more productive in stimulating research topics.

The Research section has gained good acceptance by top management during the past two years because it has directed its efforts at resolving Highway Department problems. The main emphasis has been on projects that will have a high payoff and result in immediate implementation. About 75 percent of the research program is financed with Federal-aid funds. One-fourth of the research effort is for nonresearch problem-solving projects and for the evaluation of new products offered to the Highway Department.

In addition to its research and development activities the section has been assisting in the development of a maintenance evaluation and training program similar to that done in Virginia. Currently four of the staff working on the maintenance training program are being financed from the research budget.

Contract research with the state universities is funded on a project-by-project basis. The Highway Department has developed a procedures manual for highway research projects that sets forth specific requirements for proposals to be undertaken for the Louisiana Highway Department in cooperation

with the Bureau of Public Roads. In addition the department has a standard research contract that is executed for each project to be done under contract. The department attempts to obtain a work plan at the same time as a proposal. Each unit head that is assigned the contract research projects in his area meets with the researcher and the Bureau of Public Roads every 60 days to review the project. Final drafts of research reports prepared under contract are reviewed by a committee of the Research section to determine whether the requirements of the contracts have been fulfilled. After the draft of the final report has been reviewed, it is returned to the contractor, who then has 60 days to file a final report with the department.

The universities have different policies toward the remuneration of faculty for contract research work. At Louisiana State University the faculty teaching load is reduced in proportion to the research load. At Louisiana Polytechnic Institute the faculty member carries research as an overload and is paid on an overtime hourly basis.

All research that is funded with HPR funds is administered by the Research section. With the reorganization of the Research section in 1965 there was a substantial expansion both in the in-house and contract research programs. Because there have been sufficient funds to finance all desired research projects there is currently no formal procedure for setting up project priorities. Projects have been selected primarily on the basis of Highway Department interest and applicability of potential research findings. The budget for research is based on the previous year's rate of expenditures. The state highway budget is set up according to objects of expenditure, with the contractual budget included as a separate item. Louisiana uses general funds as well as highway-user funds to finance the total highway program. Between \$50 and \$100 million per year of general fund moneys, in addition to dedicated funds, are allocated for highways.

With the organization of the Research section new research staff was needed. Many sources are being tapped for research personnel, among them universities, district laboratories, and engineering staff, and students interested in working while studying for an advanced degree.

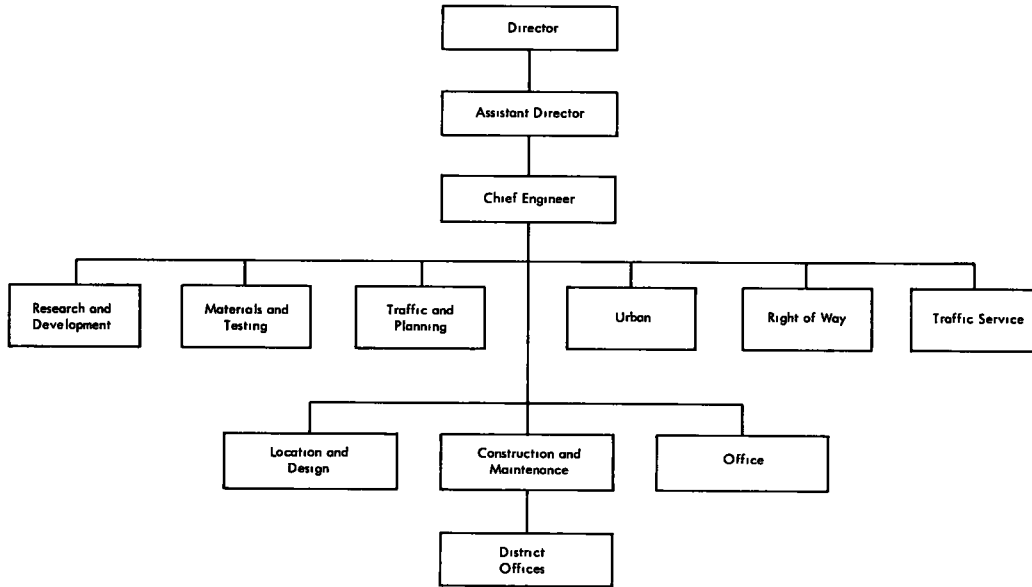
The Louisiana State Highway Department is covered by a civil service system and all positions up to that of chief engineer are included under the system. However, the recruitment and promotion of personnel is flexible enough so that noncompetitive positions can be authorized in order to permit the progression of staff within a unit. The primary criterion for promotion is longevity of service where there is equal capability of individuals.

In order to get an adequate pay structure for the principal researchers, the positions have been classified at assistant section head levels. The civil service classification system is not yet willing to recognize technical knowledge or research ability as a criterion for salary structure, and, therefore, it is necessary that senior research staff be assigned administrative responsibility for separate research sections.

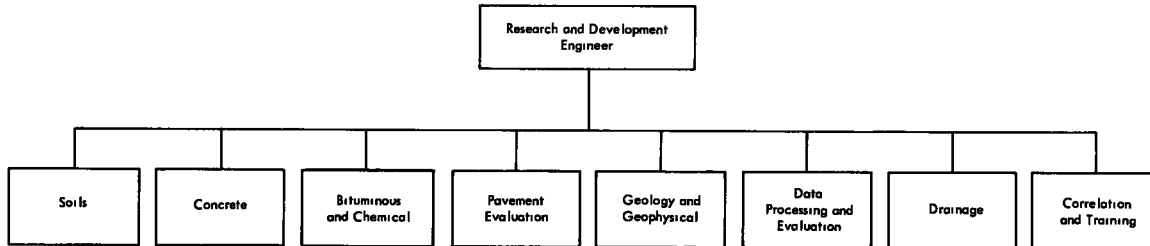
The Research section does not have any formal graduate assistantship or fellowship program. There are two graduate students working for the section who are using their research for their theses requirements. Recently the section was able to hire two of the five seniors who were employed as part-time student help during their undergraduate studies.

The Research section finds it advantageous to be located on the Louisiana State campus. The engineering faculty is thus available for consultation and for assisting on research projects. The university location also provides a source of inexpensive part-time student help. The Highway Department and the university are planning a new highway research facility that will be located on university grounds.

Louisiana



Louisiana Research and Development Section



Recently one of the staff members was assigned the task of implementing research findings from both national and state-initiated research projects. His duties consist of reviewing research reports and then contacting the interested engineering or administrative section to determine whether or not the findings have application to Louisiana conditions. If it is found that there is application, then means of implementation are discussed and instituted.

MICHIGAN

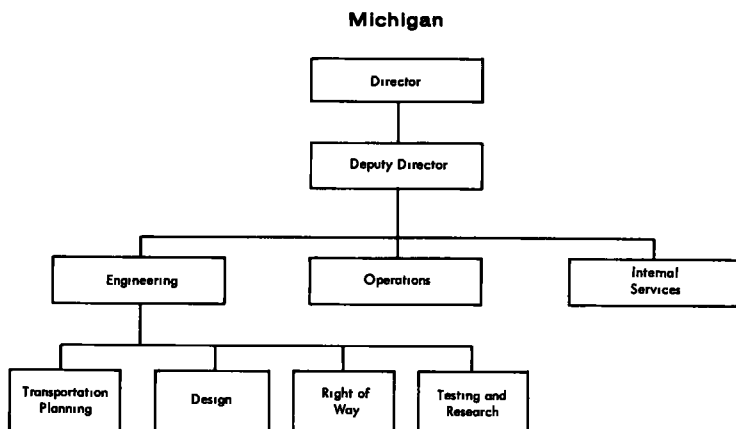
The state, the universities, and the automotive industry in Michigan are all greatly involved in highway research. At the University of Michigan, there is the Highway Safety Research Center, the Transportation Research Institute, and the American Academy of Transportation. At Michigan State University there is a Traffic Safety Center. The major automobile manufacturers operate expansive research and proving grounds in Michigan. It is not surprising that the state has had a highway research program for 38 years.

Since 1965, Michigan's four-man highway commission has been appointed by the governor rather than elected. The commission has one director and a deputy director with three bureau chiefs—one in charge of engineering, another in charge of planning, and the third responsible for internal services. The primary research facility within the department is located under the Bureau of Engineering in the Testing and Research division. Field studies, including materials testing, soils analysis, and research activities are combined under the Testing and Research division. Research facilities are housed in a separate building in Lansing; the materials testing laboratory is located in facilities provided by the University of Michigan.

HPR research projects are determined by the Highway Planning and Research policy committee, which is composed of the deputy highway director, chairman; director of engineering, vice-chairman; chief planning engineer; testing and research engineer; director of finance; and highway planning and research manager, secretary. The policy committee determines the magnitude of the HPR program and the allocation of funds. It sends a letter to all operating divisions asking for HPR and NCHRP research topics. The committee meets monthly to review planning activities and quarterly to review HPR research progress.

The Research laboratory conducts departmental research studies at the request of other agencies, such as Design, Construction, and Maintenance divisions. Planning and Traffic divisions perform in-house research to a limited extent to meet their own needs. In previous years the Right-of-Way division maintained a substantial right-of-way severance damage study program. The department lets contracts to the universities for research it is unable to accomplish itself. The research program is mainly directed to applied research.

A committee for investigation of new materials reviews materials or equipment submitted to the department to determine if testing by the Highway Department is justified. The Research laboratory does a substantial amount of testing of new materials referred to it by this committee.



The Research laboratory of testing and research has a staff of approximately 70 full- and part-time employees. The laboratory was initially established in 1939 on the campus of Michigan State University by written agreement between the university and the State Highway Commission. In 1962, in order to get sufficient quarters for its expanding program, the research laboratory was moved to separate facilities in Lansing.

The Research laboratory has five sections: materials research, spectroscopy and photometry, physical research, soils and aggregates, and administrative. Since its creation in 1959, the new materials committee has referred 180 products or processes to the laboratory for evaluation; approximately 60 are presently being evaluated. Materials testing has increased 300 percent within the last several years and the laboratory program is moving in the direction of increased nonrepetitive type testing. In addition to the tests conducted in the research laboratory a number of tests have been done in cooperation with the Automobile Manufacturers Association using the manufacturers test sites.

Since the research laboratory has been physically separated from the Michigan State campus, there has been less contact with the university. However, there are currently 12 student assistants employed. These students generally are studying mathematics and science. They are used as technicians, and there is little opportunity for them to use their research activities as a thesis project.

Printed reports prepared for national agencies, such as HRB, ACI, and ITE, are distributed outside the department, but reports, which generally cover specific assignments and are not of general interest, are not.

Research findings are implemented through action by the committee to investigate new materials and by direct recommendations for new or modified specifications in concurrence with other divisions.

The traffic and planning functions are separate in the Michigan Highway Department. Planning is under the Bureau of Engineering while traffic is under the Bureau of Operations. Within the Traffic division there is a separate traffic research section with nine research engineers. Until it was brought under the NCHRP program, the John Lodge Freeway Traffic Surveillance Study was this section's responsibility. The present research budget for the Traffic division is over \$400 thousand, which is primarily for a study of rural freeway communications systems for stranded motorists and for traffic surveillance studies on the freeway.

Less than \$100 thousand of highway funds are under contract with the state's universities. The total HPR Part II research funds amount to approximately

\$700 thousand. The Research laboratory is involved in materials, design, and construction studies and indirectly in some traffic studies. The Research laboratory studies consist of approximately \$150 thousand for HPR and \$350 thousand for state allocated to Research.

The universities are expanding their research in safety and other nonphysical research areas. These are primarily financed by industrial grants. The new \$10 million Highway Safety Research Institute is financed by the Automobile Manufacturers Association and is located at the University of Michigan.

Michigan feels that research is of enough importance to warrant review and supervision by the highway director and other top administrators. The department feels that the research laboratory lends itself to physical research and materials testing activities, and that other divisions within the department should perform research in the planning and administrative activities.

Recruiting and staffing for research is a problem in Michigan as it is in other states. Recently the research laboratory lost 12 staff members in lower job classes because of low salary structure and lack of opportunity for advancement.

MISSOURI

In Missouri the Highway Department consists of a central office and ten district offices. The district offices play an important role in this organization, and each district has its own staff for construction, materials, surveys and plans, maintenance and traffic, and right-of-way.

The research program of the Highway Department is primarily mission-oriented. With few exceptions, research projects are designed to yield results that can be immediately applied to the solution of the state's problems. While the results of this research are frequently applicable in other states, projects of nationwide interest and scope or highly theoretical research problems are supported mainly through sizable financial contributions to the National Cooperative Highway Research Program of AASHO.

Most department research projects are financed with 1½ percent HPR funds. Projects financed in this manner are collectively referred to as the Missouri Cooperative Highway Research Program. This program is developed on an annual basis and, to date, sufficient HPR funds have been available to finance all projects deemed worthy of inclusion in this program.

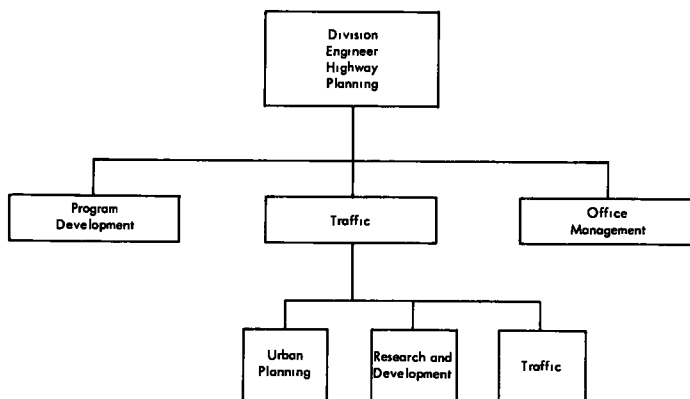
All research carried on within the department or contracted by the department is done with the approval of the Research Advisory Committee. This committee is composed of five members and meets as often as necessary to review current research and pass on proposed projects. It also passes on the continuation of current research and approves all progress and final reports.

Proposals submitted to the committee are referred by the head of one of the functional divisions of the department to a member of the committee for presentation. Proposals originating outside the department must be sponsored by the division engineer responsible for the area of interest and are then referred to a member of the committee for presentation.

In recent years, all of the in-house research within the department has been conducted by two divisions: Highway Planning, and Materials and Research. All other research sponsored by the department has been done by contract with outside agencies. The research responsibilities of the Highway Planning division are assigned to its research and development section. The section is responsible for the administration of the Missouri Cooperative Highway Research Program and for the conduct of traffic and planning-oriented research. The research responsibilities of the Materials and Research division are assigned to its research section, which is responsible for the conduct of the physical research conducted by the department.

A substantial portion of the department's research has been done by contract. No specific portion of each annual budget is set aside for this research. Research is done under contract when the department does not have qualified personnel or proper facilities, when the workload will not permit in-house research, or when the contractor possesses some special competence or research facilities. Much of the recent contract research has been performed by the University of Missouri at Columbia.

Missouri—Highway Planning Division



NEW YORK

New York has a substantial in-house research program. Only \$247,000 of a research budget of \$1.7 million for 1967-68 is allocated for contract research. The remainder is for engineering research done within the New York State Department of Transportation.

The Bureau of Physical Research was established in 1958 with an authorized staff of 34 people. In 1966 the authorized staff was increased (for the second time) from 54 to 160 positions. The bureau is part of the Technical Services subdivision, which is under the direct responsibility of the Design and Construction division. The Technical Services office is responsible for three bureaus: soil mechanics, materials, and physical research. While the Bureau of Physical Research has primary responsibility for research, the Bureau of Materials and Soil Mechanics do special research problems. The Bureau of Soil Mechanics has a special unit devoted to research and development and the Bureau of Materials has a new materials statistics section.

The current expenditure rate for the Bureau of Physical Research is approximately \$1 million a year. The 1967-68 fiscal year's budget is \$1,700,000 if all positions are filled. The program is financed primarily with Federal-aid HPR funds, and all research within the section is engineering research. Research is primarily aimed at solving field problems, and 90 percent of the research is applied research.

Whereas a number of states depend on coordinating committees for review and approval of research programs, New York depends on the administrative staff in physical research to plan and coordinate the program. The deputy chief engineer for technical services and the director of the physical research bureau, with the suggestions of the staff and operating engineers, decide on the research program. As indicated by the rapid growth of the research bureau, there has been significantly more research requested than there has been staff to perform the research. Eighty percent of the research projects are suggested by the operating divisions; only about 20 percent is the result of staff interests. The overall content of the physical research program is based on the needs of the Department of Transportation and the availability of staff to perform the research. The research program is tailored to fit the department's needs rather than the interests of the researchers. There is proportionately less contract research with colleges and universities in New York in comparison to other states. Universities interested in engineering research submit proposals to the department. About half of the contract research program is for continuing research projects at the universities.

One of the most important factors influencing New York State's engineering research program is the state's fund structure and budget control system. Most states have constitutional provisions or antidiversionary statutes under which all funds collected from highway-user taxes are allocated for highway purposes. In New York State, however, all revenues collected from highway-user sources are deposited in the general fund of the state. Appropriations are made by the legislature to the Department of Transportation out of the state's general revenues fund. In states where highway-user revenues are dedicated for highway purposes, the legislature and executive budget office generally do not exercise substantial control over the highway program. How-

ever, in New York where the transportation program is in competition with other state functions, both the legislature and the executive budget offices exercise close budgetary control.

The appropriation of funds to the department is based primarily on historical expenditure patterns plus new construction programs. While the department is attempting to develop a greater appreciation for program budgeting, current allocations are based on line item appropriations by objects of expenditure. In contrast to other states in which the magnitude of research is based on a percentage of HPR funds available to the state, the level of research in New York is determined by the number of authorized personnel positions and the line item amounts approved for operating expenses and capital outlay.

There is no research advisory committee. However, there is a detailed yearly review of all HPR projects with the Bureau of Public Roads in a formal presentation made to the Bureau of Public Roads by the staff of the Bureau of Physical Research. The liaison between the Physical Research bureau and the other operating divisions of the Transportation Department is the responsibility of the research administrators. Three new positions have been requested for the next fiscal year to augment communication between research and operating personnel. Since the deputy chief engineer for technical services is also responsible for changes in the department's specifications, research findings may be put into practice through this channel. One of the characteristics of the State Department of Transportation is the delegation of responsibility and authority to the deputy chief engineers. These engineers are contacted and sold on the findings of research projects.

The State Department of Transportation is operated under a civil service system. The system is very much like the Federal civil service system and requires an applicant to pass an examination before he is certified as being qualified for a position. Position lists are prepared, and selection for a position must be from one of the top three persons on the list. Written tests are used to determine qualifications. All positions within the department through the division level are subject to competitive examination and all persons qualified may compete for the position. One advantage of such a system for research personnel is that research need not be a dead-end to advancement with the department, since they may transfer to other positions in the department.

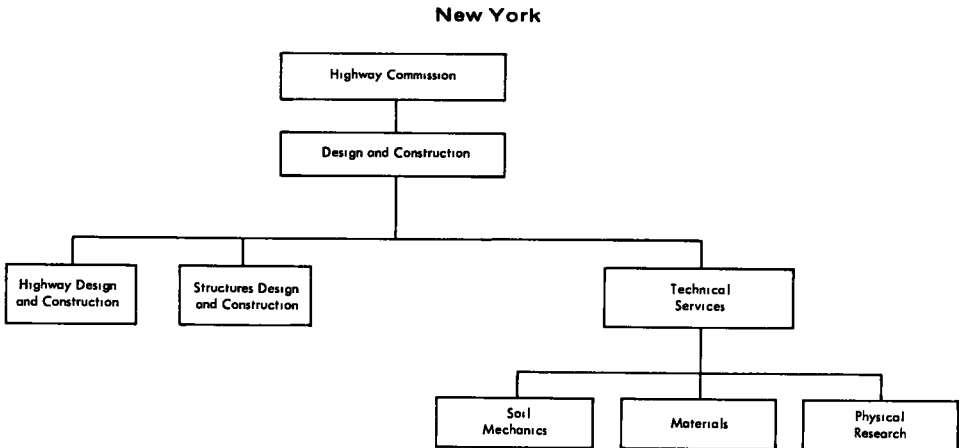
Pay scales are classified according to the state civil service system and there is no premium pay for research capability or experience. Because of its rapid expansion, the Bureau of Physical Research has been engaged in an extensive recruiting program. The primary source of research personnel is recent graduates from colleges and universities. Six of the staff have their masters degrees, five others are working toward masters degrees, ten have a bachelors degree, and 36 of the technical level staff have two years of college preparation. Fifty new staff members have been recruited since June 1966. One-half of the engineering staff are taking graduate courses. The department has a program under which employees may be released from work obligations for up to three hours per week and may be subsidized for between 75 and 100 percent of their educational expenses for advanced degree work.

During the summer the Physical Research bureau hires faculty and students to do research both with the Transportation Department and at universities. In this way the department can obtain specialists at moderate cost. Most of the staff in the Research bureau are not specialized and work on research projects as needed.

New York does not maintain a new product evaluation section and the materials division does new product testing. If it can be included as part of a re-

search project, new products are evaluated within the Physical Research bureau.

The Bureau of Physical Research uses most of the Federal-aid HPR Part II funds made available to the department. The Bureau of Planning under the Office of Transportation Planning and Programming maintains a research and applied systems unit financed with Part I and some Part II HPR funds. In 1965 a research unit was established in the Bureau of Planning to develop urban and statewide transportation planning techniques. There is also a special studies unit which has been studying emergency communication services for stranded motorists and wrong-way drivers. Other in-house research is conducted by the Bureau of Soil Mechanics, which is coordinated by the Bureau of Physical Research and the Bureau of Landscaping. The Division of Traffic Engineering and Safety does traffic studies.



NORTH CAROLINA

The North Carolina highway research program is characterized by strong administrative and budgetary controls. The Department of Planning and Research is responsible for the administration of North Carolina's research program. The planning and research engineer is directly responsible for the supervision of the program. Most of the research conducted by the North Carolina Highway Department is by contract with North Carolina State University. Presently there is slightly over \$80 thousand allotted to in-house research, which is used primarily for salaries for maintenance research, interstate accident data collection, research on the evaluation of new products and materials, and administrative costs. Under an annual agreement, North Carolina State University receives from 8 to 12 projects using approximately \$150 thousand of HPR funds.

To supervise the research program, a State Highway Commission steering committee has been created. This committee contains six members from the Highway Commission, six members from the state university, and two representatives from the Bureau of Public Roads.

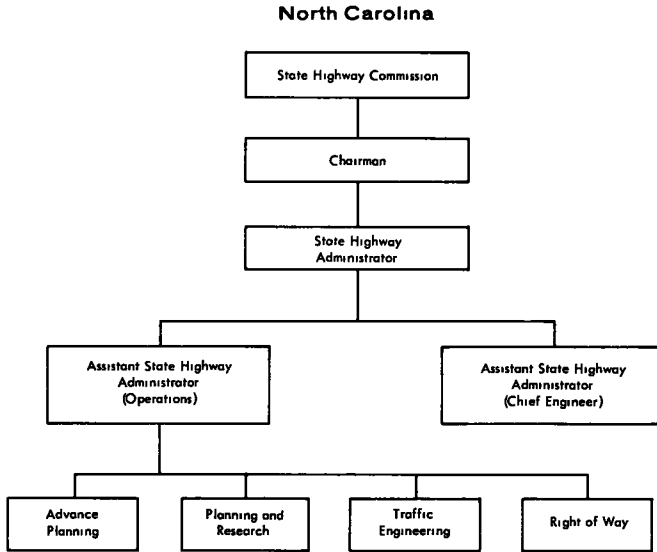
Although there is not continuing cooperative research agreement between the state and the university, research is supported by the state at approximately \$150 thousand a year. In the past, research projects were recommended or suggested by university faculty members and by agencies of the Highway Department. The present procedure is for the planning and research engineer to canvass the departments and operating divisions of the North Carolina Highway Department, Bureau of Public Roads and the university for research topics. The topics are then referred to subcommittees operating under the steering committee.

A list of desired topics is then sent to the university to determine if there is interest by the faculty in any of the topics. Where there is an interest the university prepares detailed research proposals for submission to the steering committee. After approval, the proposals are incorporated in the research program and submitted to the Bureau of Public Roads for review and approval. If more proposals are submitted to the Bureau than there are funds to finance, the Bureau is asked for tentative approval pending inclusion in a future program.

A standard contract has been prepared by the Highway Department and approved by the Bureau of Public Roads whereby all projects are approved under one agreement for the following fiscal year. The contract provides for the duration of the project, and the budgeted amount for each project. The amount budgeted for each project is based on a detailed prospectus.

The North Carolina highway research program is supported with Federal-aid HPR funds and state matching funds. The state uses both the 1½ and the extra one-half of 1 percent Federal-aid funds made available for planning and research. Currently, approximately 20 percent of the planning and research funds are allocated for research.

North Carolina operates under tight fiscal controls. Whereas many other highway departments are permitted by their legislatures to spend all funds derived from highway-user taxes and other earned funds, the North Carolina highway budget is appropriated by line item and expenditures are controlled by the state's Department of Administration. The Department of Administra-



tion, through the budget office, maintains control over expenditures, and excess funds not appropriated go into unallocated surplus.

Not only does the Department of Administration provide budgetary controls, but the legislature (which meets every two years) also maintains very close control through an advisory budget committee. Before any budget item is approved by the legislature, it must be reviewed and approved by the committee, made up of legislature members. Once the budget is approved, it goes to the Department of Administration to be used for control purposes. Since changes in the research program are subject to review of both the Executive Budget Office and the legislature, with all highway funds allocated by legislature appropriation, the research program has remained relatively fixed and a rapid increase is not anticipated in the future.

Once a project is approved by the steering committee and has been included in the research contract with the university, a liaison committee is created for each project. The liaison committee consists of the research staff for the project, the research coordinator for the university, the research engineer from the Bureau of Public Roads, the research engineer from the Highway Department, and an additional member, who is interested in the project, appointed from the Highway Department. Frequently, if the project was suggested from within the department, the person making the suggestion is designated. An additional engineer for the Bureau of Public Roads is specifically assigned to monitor each project. The liaison committee meets quarterly to review the progress on the project. If the project was the result of the suggestion of a Highway Department official, he is usually made the chairman of the liaison committee. It is his responsibility to review the project and inform the planning and research engineer of any problems encountered in the execution of the research. It is the responsibility of the chairman and the research engineer to see that project findings are made available to the interested departments of the Highway Commission so they can be put into practice. The Materials Testing laboratory does not participate in research because it is totally involved in testing activities of the present time.

Compared to other states with large research programs, North Carolina's research program is limited. The program is geared heavily to payoff and immediate results, rather than toward basic research or sustaining the university's education program. However, the university is allowed to use graduate assistants on research projects.

OHIO

The Ohio Department of Highways allocates approximately \$2 $\frac{1}{4}$ million per year of HPR funds for highway research. About \$1 million of this is for contract research with Ohio State University, and another \$ $\frac{3}{4}$ million for contract research with other colleges and agencies. Between \$ $\frac{1}{2}$ and \$ $\frac{3}{4}$ million is used for research performed within operating units of the Highway Department.

Research has received additional emphasis since the Little Hoover Commission study in 1963. Since that time both in-house and contract research have substantially increased. Both the current and the previous governors have endorsed the need for highway research. Ohio's highway research program is directed toward both state needs and toward national transportation problems. The program is balanced between physical and planning research.

The department performs as much research as possible within the operating units. Where this is of such magnitude as to justify special research units, they are established. Within the department there are research units in the divisions of traffic and right-of-way. Research is also being done in the materials testing laboratory, and in the maintenance, construction, and aerial engineering sections of the Bureau of Location and Design and Planning Survey. The highway program is administered by the engineer for research and development. To assist him in this function he has an assistant engineer, who is currently located at The Ohio State University and is acting as liaison between the university and the Highway Department.

A research and development advisory board was set up in 1963 to review and advise the department on matters relating to the research program. The advisory board has 16 members from the department's staff. The Bureau of Public Roads is represented in an ex-officio capacity. The board, which meets as required, has devoted most of its time to general policy recommendations and research activities being conducted at the universities and within the department.

Coordination of research contracts is done by the engineer for research and development. For each contract a department liaison representative is designated from the division or bureau most interested in the research topic. It is the function of the liaison representative to review and make suggestions relating to working plans, progress reports, and final reports of the contractor.

Ohio is a highly urbanized industrial state. It is fortunate in having colleges of engineering in 7 of its 12 highway districts. Ohio State, the University of Cincinnati, the University of Dayton, the University of Toledo, Ohio Univer-

sity, University of Akron, Case Institute, and Battelle Memorial Institute currently have research contracts with the Highway Department.

Ohio State University has a major portion of the research contracts with the Highway Department. Up until the late 1950's the Highway Department maintained a testing and research laboratory on the Ohio State campus. With the relocation of the testing facilities and the increase of materials testing requirements for the Interstate highway construction program, research in the materials laboratory was curtailed. Beginning in 1960, with the backing of the governor, contracts were let with the university for a number of theoretical research projects as well as those directed toward solving specific highway problems. During the period of time that the research program was being expanded, the university financed the necessary staff time and expenses to get the research program optional.

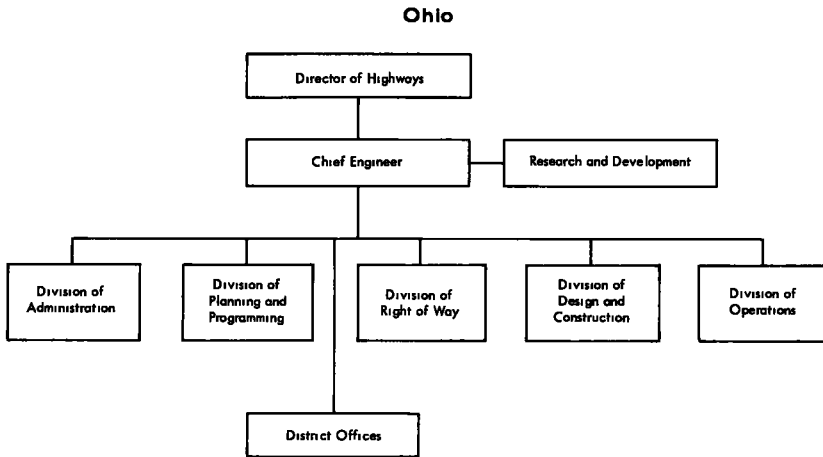
The research program at the university is dependent on the availability of faculty who want to do research. The faculty receives no extra compensation for research; however, the teaching load is reduced proportionally. The tendency is for the faculty to suggest research studies of particular interest to them. These must be oriented to the specific needs and possible application within the department in order to be included in the highway research program.

There is no sustained level of highway research at Ohio State University by the Highway Department. However, funds have been sufficient to carry on a comprehensive program. A few of the university's research contracts are long-term projects but most of them are for two or three years. The university uses the contract research program to subsidize its graduate assistantship program by providing research from which students may develop masters or doctoral theses.

In 1965 Ohio State University became interested in developing a small test tract of about 400 acres for the testing of highway materials, equipment, and traffic systems. Initial contacts were made with the Highway Department and the governor's office to determine potential interest. The proposal was met with great interest by the governor, and a committee was created to review the possibilities of developing a major transportation research center near the Ohio State campus. The governor and the Department of Development believed that such a research center would be beneficial not only to the university but also it would aid in the industrial development in Ohio. Therefore, the proposed research center was expanded to a 5,000-acre site, costing \$25 million, to be constructed in a 10- to 15-year period. Two million dollars has been appropriated for the acquisition of the site. More than a hundred industrial concerns have contacted the university indicating their interest in the proposed transportation center. The university has not yet hired a full-time administrative staff to develop the center.

Currently all work is being done as overload by the director of the highway research program and the faculty. There has been no funding of the project other than the appropriation to acquire the site.

It is the philosophy of the university that research should primarily assist the faculty and students in furthering the instructional program and not be an objective in itself. Therefore, the goals of the new transportation research center are not yet clearly defined. On the one hand, industrial interests are anxious to have a facility where they could do testing and developmental work not directly related to the instructional program; the university, on the other hand, does not want to develop an independent research institute unconnected with the instructional program. The possibility of orienting the center toward materials and equipment testing is being considered.

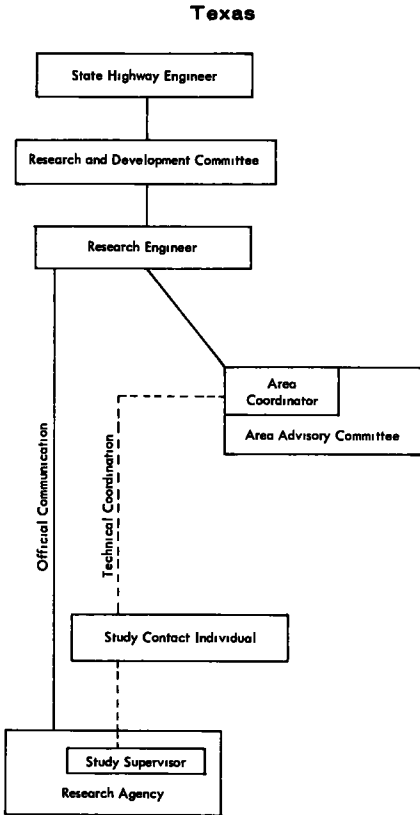


Since 1963, research activities within the Highway Department itself have similarly expanded. A research section has been established within the Bureau of Traffic. In addition to planning studies, the section has eight studies relating to traffic and traffic control devices. Also, the staff has been designated as liaison representatives for the Highway Department for eight research contracts with the state universities.

Research reporting processes include those required by the Bureau of Public Roads for HPR projects. Instructions have recently been issued regarding liaison and review as well as reporting research results that have been widely distributed by the Bureau of Public Roads as suggested procedures for others to follow. Highway Department liaison representatives for contract research are designated from areas closely related to the research. They have proved to be an effective way of translating research findings into operating procedures and specifications. The engineer for research and development is also on the specifications committee and brings proposed changes based on research findings before the committee for action and implementation.

TEXAS

Prior to 1953 very little formal research was conducted by the Texas Highway Department. In 1953 a Research and Development committee was appointed. This committee was charged with the responsibility of looking into the research needs of the Highway Department and developing a program to satisfy these needs. The administration of the research program was vested in a Research section within the Highway Design division. The Research section was headed by a research engineer and a staff capable of administering the research program.



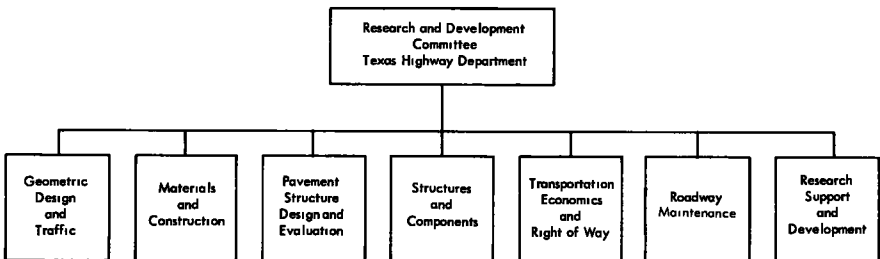
By earlier legislation, Texas A&M University had been authorized as the official research agency for the Texas Highway Department. This provided the necessary basis for the cooperative research program, which was initiated in 1956. In order to facilitate this work, Texas Transportation Institute (TTI) was established as a research arm of the Texas A&M University system and this agency, in cooperation with the various divisions and districts of the Highway Department, began to develop research proposals which were submitted through the research engineer to the Research and Development committee for consideration. In 1956 research projects totaling \$150 thousand were approved by the Research and Development committee, with the research being conducted by the TTI.

The program has now expanded to approximately \$2 million per year, of which approximately \$400 thousand is used within the department. TTI conducts over \$1 million in research per year and the University of Texas over \$500 thousand.

To more closely coordinate the progress of the various research projects with the needs of the Highway Department, a committee consisting of Highway Department personnel was appointed to work with and advise the project supervisor in each of the projects. This system worked well until the number of projects became so great that a committee for each project became an unwieldy situation.

In 1966 the Research and Development committee established seven research areas. An area advisory committee was appointed for each area and each research project was assigned to one of these areas. These area committees consist primarily of field personnel of the Texas Highway Department,

Texas—Areas of Research



with an area coordinator who acts as secretary to the committee and is in most cases a member of the staff of the Research section. In addition, a liaison officer is appointed for each individual project. Each area committee elects a chairman from its membership. This chairman in most cases is the district engineer. These committees serve a number of purposes. They review research needs and make recommendations to the Research and Development committee and also work with the various research projects in coordinating the work with the needs of the department and in disseminating research findings.

Each year the various research agencies prepare project proposals with the advice of the area committee and in cooperation with interested divisions of the headquarters office. These proposals are then reviewed by the Research area committee, the research engineer, and the Research and Development committee and are submitted to the administration of the Highway Department for final approval. In most cases an individual from a central office division will act as a liaison officer for a project.

A limited amount of research is conducted within the Highway Department. Projects undertaken by the Materials and Tests division are sometimes financed with state funds rather than becoming a part of the HPR program. This division, plus other divisions, however, does conduct HPR projects when it is determined that a particular need can better be fulfilled in this manner.

Since the amount of money available for HPR uses is established by Federal allocation, the funds available for research are dependent on the amount required for urban planning studies. If the combined needs of planning and research exceed this allocation, it is necessary to determine what specific activities (either in planning or research) should be curtailed or whether or not additional state funds should be provided.

A research digest containing abstracts of current Highway Department research activities and important national research findings is published each month by the Research section. "Texas Highways" also provides an excellent medium for relaying research findings to highway personnel and others. The highway short course, which is widely attended by highway engineers throughout the state, also provides an excellent means for making research results known to those who can make use of the information. Personal contact between field people and personnel involved in the research program is another excellent way of conveying information.

Until 1965, TTI conducted the bulk of the highway research in Texas. At that time the legislature provided for an expansion of the research program to include other agencies. Although the University of Texas is the only other institution to have become involved in the program to any great extent, the program is not limited to these two organizations. One project is being carried on by the U. S. Geological Survey.

In recent years a great deal of interest in research by district engineers and other field personnel has been evident. This interest has in many cases been furthered by participation in the work of research area coordinating committees, and it has resulted in a high degree of acceptance of research information by field personnel, since in many cases they have also participated in the development of this information. This is highly desirable since the decentralized nature of the Texas Highway Department leaves many important decisions to the district engineer.

TEXAS TRANSPORTATION INSTITUTE

In 1949 the Texas legislature approved the creation of the Texas Transportation Institute (TTI) at Texas A&M University. However, it was not until 1956 that TTI began functioning with an initial budget of \$150 thousand. Today, it has \$3 million in research contracts, of which over \$1 million is with the Texas Highway Department. Because of the overlap of contracts, the actual annual rate of expenditure is about \$2 million per year.

The cooperative program between TTI and the Texas Highway Department was put on a firm basis in 1960 with the development of a five-year program. Funding is on a project-by-project basis, but there is an effort by the Highway Department to eliminate large fluctuations in the level of support in the various research areas from year to year. The remainder of the TTI program is sponsored by industry, Federal agencies, and associations.

TTI is a part of the Texas A&M University system. It is administered through the Texas Engineering Experiment Station at Texas A&M University under the Dean of Engineering. Its stated objectives are to perform research, to provide a source for funding of graduate student research, to disseminate research information, and to serve as an official research agency of the Texas Highway Department.

TTI is divided into several research departments, a library research department, and a publications department. There is also a safety proving grounds at the Texas A&M research annex and a highway safety research center operated as a part of the Institute. There are currently over 45 full-time equivalent professional level positions. The total professional staff numbers over 70, of which approximately half are joint appointments with university departments and half are full-time research staff.

The major problem in joint appointments for both teaching and research is to keep the energetic, dedicated teacher-researcher from overloading himself in both areas. The administrators responsible for the instructional and research programs must see that the individual makes a realistic division of his time between the two programs that will permit him to make his maximum contribution. TTI employs research faculty on a 12-month basis and prefers that the individual researcher participate in the research program on a continuing basis.

The contract research contributes to the academic program by providing funds for supporting graduate student research and the research interests of the faculty. There are currently over 40 graduate students employed as research assistants. The research assistants work 20 hours per week on contract research projects. Research in which a graduate student is involved may be used for a thesis and an appropriate amount of academic credit is given for his research activities. The graduate research assistantship program has provided a source of research staff for the Institute.

The salary structure is based on a merit system and is closely tied to the university salary structure. Full-time research staff have equivalent rank as other members of the faculty of professional staff throughout the university.

During the last two decades, both in industry and government, there has been a narrowing of salary spread. The lower salary levels are moved up more quickly than the upper salaries. This has resulted in a decreasing emphasis on salary as a primary motivating factor for advancement. However,

at Texas A&M, the university philosophy is to maintain as broad a spread in the salary structure as possible and to encourage professional advancement and promotion upward or out. Both experience and academic training are considered in recruiting and advancement in rank at TTI.

Within the research program, there is no distinction made between fundamental and applied research. A philosophy of the Institute is that transportation research must be put to work if we are going to catch up with present demands for transportation. To be most successful, the full cycle of research must be completed. This cycle includes formulation of theory, verification through experimentation, and validation through practical application, with feedback from such use into the theory for additional modification.

The heaviest area of research is currently in highway transportation. Research studies are developed by the Institute and the Highway Department cooperatively. TTI maintains cost controls on these studies and is required to stay within the total authorized budget for each one. There is a provision whereby allocation may be shifted among studies with justification and with the approval of the Highway Department. Each study proposal includes a budgeted amount to cover the expenditures incurred by the department.

There is a close correlation between the researcher's interest and the study to which he is assigned. The philosophy of the Institute is "You can't make a man comfortable in the wrong pair of shoes." The task force approach is used in staffing wherever possible in order that various disciplines can make a contribution to appropriate studies. The task force or team approach has been used successfully on endeavors that are suited to such handling.

Bridging the gap between research findings and their implementation is being approached in a number of ways. For the past 41 years, Texas A&M University has sponsored the annual Texas Highway Short Course, which now attracts an attendance of over 1200 from the Highway Department, cities, and other segments of the highway industry. There are presentations of recent highway research results. All research is published both in a final technical report and in a summary form. The summary reports are given wide distribution throughout the state and nation. Right-of-way conferences, community services programs, and regional seminars are held on a continuing basis throughout the state. Research is also reported in the monthly magazine, "Texas Highways," and in the Institute's own widely disseminated magazine, "The Texas Transportation Researcher."

In keeping with the assigned function to enlist the broad resources of the departments and agencies of the Texas A&M University system, the Institute has used the interdisciplinary team-approach in staffing research projects. This approach has been found to be necessary to solve the complex problems of today, which require inputs from a variety of specialties or disciplines. A problem in highway materials, for example, may require inputs from the disciplines of civil engineering, chemistry, physics, geology, agriculture soil sciences, and others. A problem in the traffic engineering field may involve the traffic engineer, mathematician, statistician, and computer specialist. Over 30 different disciplines or areas of specialization are represented on the present staff, and a variety of other disciplines are available throughout the university.

VIRGINIA

The Virginia Department of Highways utilizes three types of research: in-house research conducted by the operating divisions; contract research by universities and consultants; and research conducted by the Virginia Highway Research Council, the agency assigned the research responsibility.

The Virginia Highway Research Council is sponsored jointly by the Highway Department and the University of Virginia, and is located at the University of Virginia School of Engineering and Applied Science. Organized in 1948, it has a current staff of almost 100 full- and part-time employees, expending about two-thirds of the state's available highway research funds. The divisions of Traffic and Planning, Location and Design, and Right-of-Way do in-house research. State universities have been let contracts for highway research. The total research budget is approximately \$1 million a year.

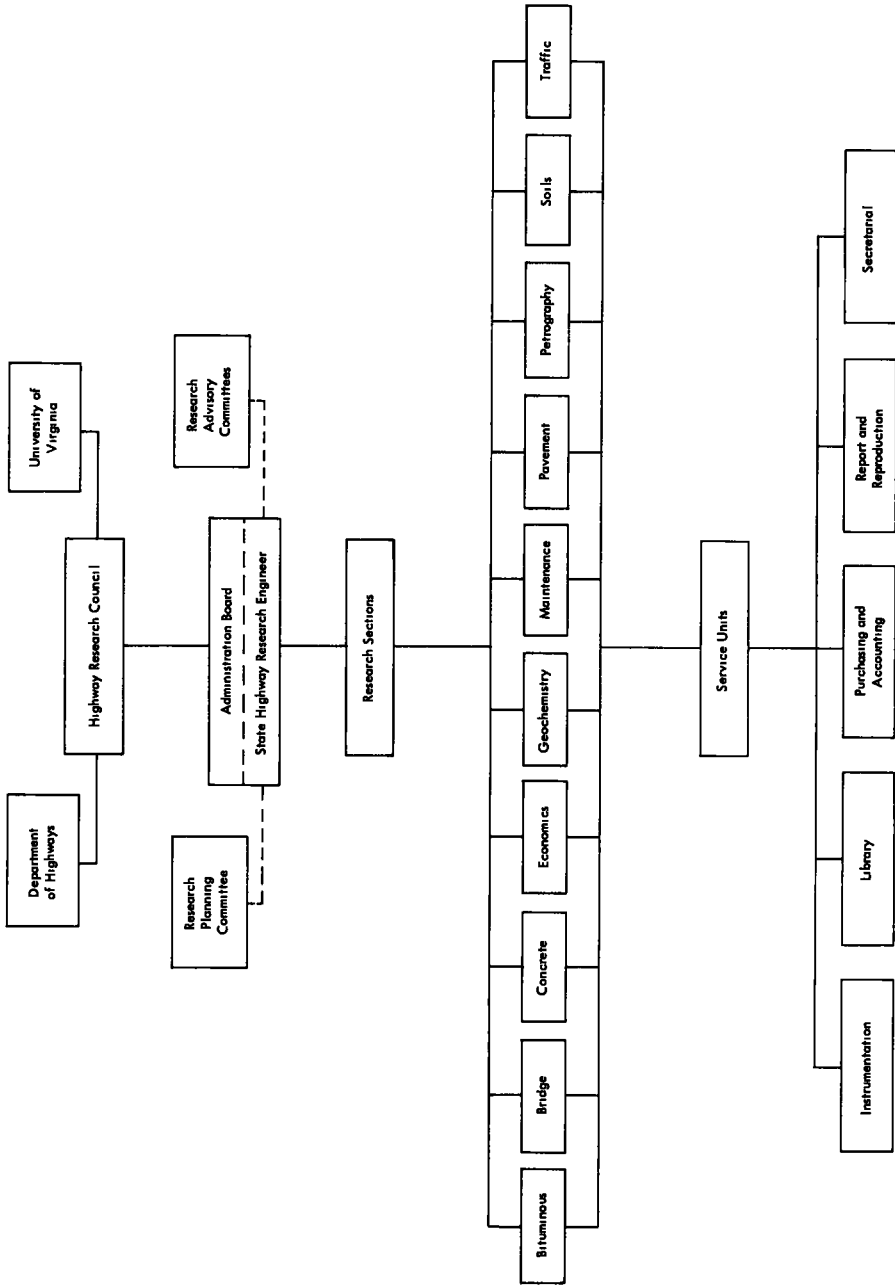
The council has a dual purpose: to conduct research for the Virginia Highway Department and to provide education and training for both university students and department personnel. The university provides the council with laboratories and office space, partly without charge and partly on a rental basis. The Highway Department bears the cost of salaries and operating expenses. Council personnel are employees of the Highway Department; however, a few Council staff members teach courses for the university upon request.

Policies of the Research Council are formulated by an administration board composed of the deputy commissioner and chief engineer of the Highway Department (chairman), director of programming and planning, state highway research engineer, dean of the School of Engineering and Applied Science of the University of Virginia, and the head of the school's Department of Civil Engineering. The state highway research engineer is the council's executive officer. The board meets quarterly to consider administrative matters and general policy. Usually it does not concern itself with the detailed research program, although it does approve the proposed budget. In recent years its primary deliberations have been devoted to salary structure, office and laboratory space, and relationships between the Highway Department and the University.

The Research Council is divided into 10 sections and 5 service units. The sections contain full-time research employees, faculty consultants, graduate assistants, student helpers, and technicians. Because of the physical separation from the Highway Department's central office, the Research Council maintains its own administrative unit and report and reproduction section.

Until 1965 the council had a highway research advisory committee, which held three or four meetings a year to review the council's research program and to approve research proposals and working plans. In addition, some of the sections had subcommittees advising them on department needs in certain specific research areas. This arrangement in recent years failed to generate sufficient interest in the research program, and a better device was needed to help bridge the gap between research and the application of findings. As a result, the council was reorganized in 1965. The advisory committee was abolished and an individual advisory committee of eight to ten persons was created for each section. Each committee meets twice a year to review the sections' research programs, to suggest research topics, and to assist in implementing the findings. Most of the committees meet during the annual

Virginia



spring materials and research conference sponsored by the council, the Highway Department's Division of Materials, and the university. In the fall and winter months, each committee meets separately. The committee members serve one-year terms, which may be renewed. Committee membership is composed of highway administrators from the operating divisions, members of the state's educational institutions, and representatives from the Bureau of Public Roads. The committees advise the sections on research, but do not have any direct control over the research program.

The primary sources of research projects are the research staff and the Highway Department, with each advancing about the same number of proposals. Generally proposals are checked with the appropriate operating divisions of the department to ascertain their interest prior to being approved by the director of programming and submitted for financing.

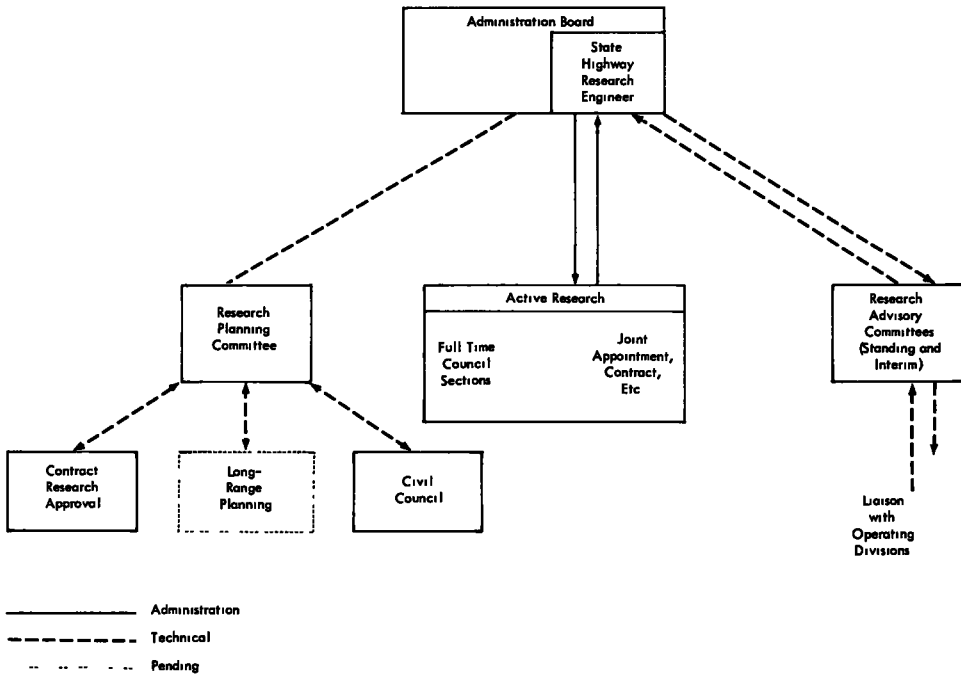
Until recently HPR funds were in excess of needs, and there was little problem in financing projects with these funds. With the urban transportation studies being financed with 1½ percent Federal-aid funds, there is presently a shortage of planning and research funds. Therefore, it has been necessary to limit contract research and the Research Council's program is being maintained at the current level of expenditure. Proposals for contract research are submitted to the administration board for review and approval. This procedure applies only to contracts administered by the Highway Research Council. The Division of Traffic and Planning and other operating divisions let their own contracts for research.

To coordinate activities between the School of Engineering and the council, a Civil Engineering Department-Council Committee was formed in 1963. The committee is comprised of two members each from the council and the Civil Engineering Department, and the chairmanship is rotated. One of the activities of the committee was to gain approval of the concept of joint appointments between the University of Virginia and the Research Council. Under the concept of joint appointments, researchers can be employed by the university for teaching purposes, and the Highway Department for research, with salaries being prorated.

In 1966 the council created a Research Planning committee composed of the state highway research engineer, two council staff engineers, two additional members of the Virginia Highway Department, five members from the educational institutions throughout the state, and a representative from the Bureau of Public Roads. The committee's function is to suggest needed research programs.

While research is the primary function of the council, one of its stated objectives is the educating and training of men in highway engineering and other areas encompassed by highway transportation. In pursuing this objective, the council sponsors a graduate assistantship program. A graduate student studying for his masters or doctoral degree at the University of Virginia may apply to the Research Council for a graduate assistantship. Graduate assistants are paid on an hourly basis at a rate dependent on their position in the program. The graduate assistantship program is not a stipend but rather an opportunity to get research experience through affiliation with the council. The graduate assistant is rotated through several sections during the early part of his tenure to gain orientation. When he is ready to begin his thesis or dissertation, he submits a proposal, first to the university, and then to the council. He is allowed to pursue his research under the guidance of the council and the university, with the cost of facilities and resources being included as part of the council's general research program. Ten graduate research assistantships are authorized.

**Relationships of Research Advisory Committees
Virginia Highway Research Council**



The Research Council also periodically sponsors short courses and schools for the training of highway personnel and other interested persons. In the past few years the council has conducted several short courses in statistical quality control methodology on a national basis, some tailored specifically for highway administrators. It has also sponsored a number of conferences, two of the more noteworthy being the First International Skid Prevention Conference and the National Conference on Statistical Quality Control Methodology in Highway and Airfield Construction.

The council does some new materials evaluations, but because it is separate from the Materials Division of the Highway Department it is not encumbered by routine testing problems or a great amount of new product evaluation. The location at the university has provided the council with the services of specialists from the university faculty and a good source of temporary student help. It has also provided a source of permanent research staff personnel through the graduate assistantship program.

One of the problems involved in having a separate research unit at a university is that competition for staff is primarily in the academic market, yet staff salaries are hinged to Highway Department levels. Since the academic requirements for researchers are considerably higher than for normal highway department classifications there has been almost no opportunity for research engineers in the council to progress to other positions with the Highway Department.

THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

The NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

The NATIONAL RESEARCH COUNCIL was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to enable the broad community of U.S. scientists and engineers to associate their efforts with the limited membership of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

The DIVISION OF ENGINEERING is one of the eight major Divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large. Its Chairman is appointed by the Council of the Academy of Sciences upon nomination by the Council of the Academy of Engineering.

The HIGHWAY RESEARCH BOARD, an agency of the Division of Engineering, was established November 11, 1920, as a cooperative organization of the highway technologists of America operating under the auspices of the National Research Council and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the Board are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.

HIGHWAY RESEARCH BOARD
NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL
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