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Technology Transfer, the Research Process, and Creating a Productive Environment

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Contents

Transportation Technology Supply

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The scope, characteristics, and functions of transportation are reviewed to define the structure of technology needs. The impact on technology supply of the independence or disjointedness of technology components—guideways, equipment, and operations procedures—is then investigated. Each technology component shapes its technology supply stream; technology options are limited to those compatible with component supply streams. System interdependence reinforces the disjointedness of components. Railroad research and test activities and technology-sharing strategies are compared to the structure of technology supply and needs.

This paper examines the demand for transportation technology and the ways in which technology is supplied. First, building on previous analyses (1-3), emphasis will be on how needs for technology and processes of technology supply are configured or structured. Next, a review of current work on railroad technology problems, as an example of needs and supply processes, will illustrate the usefulness of our analysis and provide an interpretation of the current railroad situation. Remarks will then be made on the U.S. Department of Transportation (DOT) and the National Aeronautics and Space Administration (NASA) technology-sharing programs for transportation. A new approach developed recently for the U.S. Department of Energy (DOE) will be contrasted with DOT and NASA approaches.

TECHNOLOGY NEEDS

Scope and Characteristics of Systems

The needs for transportation technology reflect the scope and modal divisions of transportation activities and the fragmentation of markets. Transportation is a large activity, engaged in by different modes. Although each mode has its distinctive needs for technology, a common need exists for technology of fixed facilities, such as highway and rail bridges and airport and highway pavements. Each mode serves many submarkets, which are represented by firms, governments, or households, each in varying geographical environments.

A technological tradition permeates transportation. Continuing technological change is central to the history and status of the current modes. This is partly why the technological professions play central roles in deploying and managing most transportation systems.

Transportation's technological content and technological history set the stage for high expectations of continuing technological evolution. Reviews of technological trends (4), popular publications (5), and discussions of activities to further transportation progress (6) or to deal with the problems of modes (7) often reflect those expectations. The current technology is viewed as a precursor for further development. By using increases in speed to measure technological progress, the shape of the precursor-driven development curve has been examined for aircraft (8).

Much of the literature on technology transfer concerns the size of the institution, serving as an incubator for technology development and transfer, and the links between actors and classes of actors. Most theories or models are cast in terms of a set of stages. For example, the scientist affects the technologist, who affects the sales manager and eventually the market (9, 10). Each stage in the chain has an associated requirement for time, work, and monetary resources. Evidence is considerable that small institutions are relatively more innovative than large ones (11) and that regulation highly distorts the technologies developed and their deployment (12). Regulation may shield modes from competitive market pressures, enabling a technology to be developed and deployed that otherwise would not pass market tests. Or, because of its special requirements, regulation may stimulate technology, or it may dampen competition and, thus, the development of technologies to improve the competitive positions of organizations.

In the deployment of technology products, transportation equipment and guideways are supplied by relatively large organizations that are regulated, usually by extensive standards for products. Here, we would expect a low rate of technology development. In certain cases, a number of small firms engage in the transportation business (trucking firms particularly). Households can also be considered small organizations; large railroads and airlines are at another extreme. Small operations could be sources for innovation, but because their products are not in hardware form, their innovations concern how transportation is used. This speculative point seems worthy of examination. Consider recent policy that has aggregated mass transit into large organizations, which operate according to public-sector rules. This policy may be unexpectedly stifling service innovations.

Not only has transportation been swept along by its own technology, it has interacted with other technologies. The technology of the steel wheel and rail, for example, was intimately tied to the evolution of the technology of steel making. Currently, the rail industry is constrained by the inability of steel manufacturers to supply higher-grade steels in bulk and at lower prices (13). The technologies used in automobile vehicle production have affected all manufacturing processes. Assembly line (Ford) and industrial organization techniques (General Motors) were adopted early. Cost controls, use of special tools, and preassembly have been adopted more recently (14).

Perhaps a unique feature of transportation has been its impact on the distribution of technological knowledge. The geographic sprawl of the transportation plant and transportation activities has brought the technologies of transportation to every nook and corner of the world. The technologies of woodworking for ships, the shaping of metal and machinery for construction and repair of rail, and, today, the maintenance of air and automotive vehicles have distributed technological skills widely. This role of transportation in developing human skills, which seems to have gone unrecognized in the literature, has important implications for public policy.

Transportation Functions

Transportation performs several functions. An old view of transportation is that it provides access to resources. Once transportation brought salt, spices, and dried fish from great distances; now it provides access to resources of forest, farm, and mine. Modern transportation also moves products from manufacturers to markets and provides human capital (labor) for manufacturing and business. The right of access to the transportation system, a right established in medieval times, seems based on this function of transportation. Transportation enables holders of resources to find markets, and it enables individuals to engage in work and social activities.

A related view is that transportation (along with communication) is the glue that enables and supports social and economic structures and processes. The role of transportation and questions about technology are intertwined with matters of social organization. Transportation does more than enable the use of resources; its role extends to the organization of production and consumption.

These views contrast with the view of transportation as a service industry. From this outlook, society engages in activities—from shopping in a supermarket to producing commodities from land resources. Transportation is the service that enables these activities.

Still another view is that transportation is a business activity: Transportation consumes inputs and produces outputs. The cost of inputs should be minimized, profits should be maximized, and prices should be based on costs.

These different perspectives of transportation, along with the history of transportation technology and the character of transportation institutions, explain much of the literature about the need for transportation technology. From time to time in the transportation community, an outlook exists that considers the steady unfolding of transportation technologies inevitable. The recent interest in high-speed ground transportation, supersonic transport, capsules in pipelines, and personal rapid transit is testimony to this view of transportation as a system that is continually renewed by technology. The view of transportation as a service is reflected in the current search for innovations under the paratransit concept; the view of transportation as an enterprise is behind pleas for technology to reduce cost, increase efficiency, and bring prices in line with cost.

Social, resource, and organizational views of transportation are more demanding and not usually reflected in debates. The current wisdom that the transportation system is in place (and all that is needed of technology are ways to repair, reconstruct, and rebuild) is, in these broad terms, wisdom that the evolution of social organization has ended and that sufficient resources are available to society—a view to which we do not subscribe.

TECHNOLOGY SUPPLY

Although transportation institutions have a high technological content and demands for technology are expressed in diverse ways, the supply of technology to transportation is constrained. A set of interlocking circumstances, mainly institutional in nature, seems to explain this condition.

Disjointedness

Each transportation mode is formed by geographically configured guideways, equipment or vehicles that operate on those guideways, and protocol or operations techniques that determine how the guideways and vehicles are used. Thus, transportation technology can be considered as a triad, consisting of guideways, vehicles, and operations. (In pipelines, the material to be transported serves as its own vehicle.) A striking feature of transportation technology is the disjointedness of this triad. A clear example is the highway system: Guideways are supplied by the public sector, operations are affected by the decisions of firms and households as well as by an ensemble of public regulations, vehicles are supplied by private manufacturers, and decisions about their purchase are made by private markets. In addition to the public sector roles of providing guideways and prescribing service, economic, and safety regulations on operations, the system is affected by many regulatory, tax, safety, and other regulations of the public sector that are not specific to transportation.

Decision making about technology supply takes on a disjointed, incremental character. The highway supplier, for example, makes technological decisions by taking the technology components of equipment and operations as given. Transportation planning, thus, is constrained. The manufacturer considers the methods by which vehicles will be used and the guideways on which they will be operated as given and supplies vehicles to fit. These actions limit technology considerations to incremental ones.

In the instance of the highway triad, the presence of differing public and private roles partly explains the disjointedness; there is a similar role division in air and water systems. For example, the air transportation triad is made up of publicly supplied airports and airways, public and private operations protocol, and privately owned aircraft.

Even those modes whose ownership and operations are not in the public sector exhibit the characteristics of disjointedness. A striking feature of railroads is the divisions within firms of those concerned with fixed plant, equipment, and operations. Management is constantly concerned about problems along the interfaces between divisions of technology. Some current problems are those of the productivity of equipment (a problem at the interfaces among equipment purchasing, maintenance, and operations) and the impact of heavy cars on rail (a problem at the interface between equipment and guideway).

Several additional factors assist in explaining why the guideway, vehicle, and operations components of the technology triad are disjointed. A major factor is the separate technological traditions of the components. Highways, fixed railroad facilities, canals, and airports are supplied as civil engineering technology; equipment is supplied as mechanical engineering technology. In each component, strong technological traditions influence practices to be followed and peer group communications apprise professions of the availability and appropriateness of technology. Technological traditions are less strong in the operations component. In some railroad and truck firms, a management tradition is followed, although most transportation management is professionalized on the job. Operations are constrained. Because of regulation, managers have little control over pricing and service, and operations are a matter of serving those who wish to be served, considering the nature of equipment and guideways available. Thus, compared to guideways and equipment, operations range from a well-identified entity in railroads and air transportation (although with a highly limited range of available options) to an extremely diffuse situation in the highway system.

As mentioned, the literature on innovation and diffusion regards the process as a chain or an interrelated set of stages. A notion of integration has been developed about linkages between stages, for example, between those involved in technology development and marketing and those in other interfaces along the pathway from innovation to final utilization (15). A high level of integration is desirable for effective innovation and technology transfer.

The disjointedness among the components of transportation technology blocks integration. When individual components are examined, integration is considerable, for component actors belong to similar technology peer groups and have similar self-images and purposes. But a disjointedness of the technology results because its components are not integrated. Some confusion exists on this point because integrated component pathways are sometimes discussed as if they implied an integrated technology system.

When integration within components is considered further, an additional property is revealed. In theory, integration includes the following linkages:

1. Scientist to scientist,
2. Scientist to technologist,
3. Technologist to scientist,
4. Scientist to market manager,
5. Technologist to market manager,
6. Market manager to organization management, and
7. Organization management to market.

Transportation is dominated by technologists, so technologist-to-technologist links are numerous. Because of regulation, there are also regulator-to-technologist links. In some modes of transportation, especially private firms engaged in air transportation and freight movement, close technologist-to-market links exist. But, by and large, integration is in a single form: technologist-to-technologist. This domination of technology-to-technology links distorts candidates for both innovation and implementation.

The main impact of the disjointedness of technology supply is the lack of a feasible market (and pathway to that market) for total transportation technology. Such total technologies would put components of transportation systems together in new ways or create entirely new triads of transportation technologies. But transportation institutions are arranged so that little consideration is given to such options, and no base of technological knowledge considers transportation in that fashion. Instead, existing professional groups who work in transportation (civil engineers, mechanical engineers, and physical distributional-logistics people) think of what they are doing as transportation technology. Everyone is doing transportation, but no one is doing transportation.

Standardization

The relationships between the characteristics of transportation systems and the supply of transportation technology are also significant; they too affect disjointedness. Transportation networks form systems, and the tasks performed by those systems demand a high level of standardization. Thus, operating rules, guideways, and equipment are usually standardized. This standardization affects the disjointedness of the technology, because actors and institutions involved with technology components communicate with their counterparts throughout their system. These component pathways speed up the diffusion of technology within components, but, at the same time, they establish peer group interrelations and standardization problems, priorities that may divert interest from consideration of the technology triad.

The impact of standardization on the adoption of technology is both a hurdle and a hazard. It is a hurdle if the technology is to affect systemwide activities because consensus is required on the part of many adopters before the technology can be implemented. This may bias the search for technology to that which fits the standards or to technology that does not have systemwide impact. Standardization is a hazard if it can force adoption of a technology regardless of its systemwide applicability.

Two examples may help make these points. Increased automation of railroad car coupling would be highly desirable. From a technical view, the connection of brake hoses and communication links should be quite practical at the same time that rail cars are physically coupled. Labor savings and other productivity gains would be great. But requirements of systemwide standards for coupling constrain the implementation of such a technology—for all users would have to adopt such standards before productivity gains could be captured. At the same time, standards can force adoption of a technology, such as those imposed on automobile emissions. In this case, the standards did not specify the technology, only the emission controls. The systemwide implementation of the standards thwarted the so-called two-automobile strategy, which would have implemented standards tuned to ambient airshed quality and, thus, different kinds of control technologies in different markets. (To some extent, the California standards versus the standards for the other 49 states accomplish this purpose.)

INTERPRETATIONS

We have characterized transportation technology needs, their development, and transfer; now we shall (a) examine an example of technology development and (b) review technology-sharing programs. The development of rail technology will serve as the example. Our question is whether the situation we have described holds. The review of technology sharing will examine its effectiveness.

Rail Example

A recent report of the Research and Test Department of the Association of American Railroads (AAR) lists AAR funding for research and test programs and funding from other sources. It provides a description of AAR research and test activities (16). To indicate AAR technology priorities, AAR program expenditures in 1975 have been sorted, and the effort was guideway, 15 percent; equipment, 29 percent; guideway-equipment interaction, 24 percent; operations, 26 percent; and safety, 6 percent (16).

Several caveats are in order. Expenditures shown were grouped in accordance with the discussion in the AAR report, yet there is a certain arbitrariness to the grouping, for a research program may have multiple products that fit several categories. Also, the relative attention given to technology topics in the AAR budget is surely dependent on the availability of supporting funds and work elsewhere, so this is only an approximation of AAR priorities. In addition, the percentages calculated may not approximate the relative level of effort on categories of technology throughout the railroad industry. Individual railroads do research and development, as does the Federal Railroad Administration (FRA). In addition, the larger part of a technology development and implementation effort (perhaps 90 percent) occurs after research and test activities.

These caveats notwithstanding, I was struck by the ease with which expenditures could be aligned with the guideway, equipment, and operations components of the technology; how programs were rationalized in terms of these component needs; and the lack of transportation work in the sense of considering the triad of components. The 6 percent of expenditures for safety research is not a very useful number. Safety is one aspect of regulation, bounding all research activities, but there is no way to neatly define research and test activities that are responsive to regulation.

An interesting aspect of the expenditures is that approximately one-fourth of the funds is used for guideway-equipment interaction—the track-train-dynamics program of the AAR. This contradicts expectations based on our earlier discussion, which indicated that technology development and transfer are component-oriented, taking place within components, rather than oriented across components. Additionally, operations received 26 percent of the research and test budget, which conflicts with the notion presented earlier that operations are the weak link in the technology triad. A partial explanation for the amount of work on operations is rail's organization into firms, in contrast with the institutional separation of components in air, water, and highway transportation.

TRB recently made a study of railroad research needs (17, 18). The study identifies research needs that contrast sharply with the research programs of the AAR. This is not surprising; AAR support of the conference suggests that it suspected its research program to be lacking. Also, the call for research by the TRB was not addressed exclusively to AAR programs. The FRA also sponsored the conference, and other groups are involved in rail-related transportation research.

The TRB study recognized research needs in the following categories: the condition of rail transport, problems external to the industry, and problems internal to the industry. Plant and equipment, which loom so large in the AAR budget, is one of eight research categories on internal problems; operations is another.

The differences between the AAR research and test program and the recommendations from the TRB study are easy to explain. The TRB study observes that earnings are too low for the industry to achieve its full potential and that there is a resurgence of interest in revitalizing rail transport. The AAR research program represents historical and institutional views of research needs; the TRB study represents needs by considering transportation activities as a whole. The two views are quite different. Unfortunately, as the railroad industry is structured, it is difficult to see how innovations and innovative paths can be created that would be responsive to the broad research agenda put forward by TRB. Given its structure, what the industry is able to do is better represented by the AAR research and test agenda.

About one-quarter of the AAR budget is spent on operations and another quarter on interactions between guideways and vehicles. A partial explanation for the work on operations was put forward before: The railroads are operating entities. A further explanation seems to lie in those same conditions that provided the climate for the TRB report: the widespread recognition that productivity must be increased. Although competition within the regulated industry is dampened, railroads have lost competitive ground to other modes, thus the high priority of research on operations.

The priority given to research and test work on guideway interaction represents an attempt to repair a neglected problem. Equipment and guideway decisions have been made independently for too long. Current shortages of funds for guideway maintenance and the railroads' use of larger, heavier cars have forced a crisis. The high priority given to the rail-car interaction problem is the reaction to this crisis. One industry spokeman dates the problem from the early 1960s (19). Another has remarked that "there has not been enough cooperative discussion between the equipment engineer and the track engineer" (20), a condition we take to be the norm, which supports our observation about disjointedness.

Technology Sharing

DOT is transferring the results of federal research, development, and demonstration efforts to meet regional, state, and local needs (21). DiLuzio and Albin have analyzed DOT mechanisms and programs for technology sharing (22). The Transportation Systems Center maintains a program office and provides general support for DOT. Each modal agency operates its own program, and the Office of the Secretary handles matters outside the scopes of the modal agencies (for example, pipeline safety). The DOT program is linked to counterpart agencies at the state and local level.

Is there any need for a technology-sharing program? A high level of interaction and integration within the components of transportation already exists. Furthermore, because the professionals within components belong to the same professional groups, well-developed methods of communication already exist. Technology sharing may simply duplicate existing technology-transfer pathways. Indeed, the list of mechanisms and programs for technology sharing is mainly a list of things that are already being done (21, 22). Not unexpectedly, the needs expressed for technology represent a listing of the concerns of actors within technological components; responses differ only slightly, depending on whether the institution is a state transportation department, a regional organization, or that of a local municipality (22).

DOT technology sharing may be contrasted with the view of technology and technology transfer expressed by the work of the Stanford Research Institute under contract to the Technology Utilization Office of NASA. This work is commercial path and product oriented. The study team "realized that the problem-originating public-sector agency usually benefits from the technological solution only when a commercial product reached the market place" (23). The study begins with the ensemble of problem solutions that NASA has developed. These solutions are matched in some way to problems recognizable in transportation activities. Therefore, a thermoplastic material for binding rocket propellants has been put forward to improve road-patching materials, and a material developed for supersonic-transport brakes has been suggested for improving the brakes on rail cars and postal vehicles. These are examples from 10 technology transfers claimed by the study team.

This work represents only one of several technology strategies used by NASA. For example, a different strategy is represented by the extensive technological and market-analysis work done in connection with NASA short takeoff and landing aircraft programs, and another strategy is represented by NASA's long-standing relations with the aerospace industry.

Another research and development and technology transfer strategy is discussed in work recently completed for DOE (24). This work reviewed 12 major federal research and development efforts and studied the innovation process in the public and private sectors. The primary result was the proposal of a technology implementation planning (TIP) process that is currently under consideration for implementation by DOE. The key idea underlying the TIP process is that issues of implementation ought to be considered at every step in formulation of research and development strategies; decisions about research and development strategies ought to be made in terms of downstream implementation.

In a TIP analysis, the description of the desired technology merges with the question of how the product or process will be diffused. A work program and research plan then follow with regard for the diffusion process. Implementation milestones are identified, and the relaxation of barriers to implementation is considered. Thus, the research and work plans cover both innovation and implementation, and decisions with respect to resource requirements, milestones, and work to be done all are included in the total technology-transfer process. A trial TIP has been worked out for a Stirling engine (25). The TIP process is not to be confused with technology assessment; rather, it is an aid to management and program development. Technology transfer surely has assessment components, yet the primary focus is elsewhere.

Comparisons of the DOT technology-sharing program, the NASA technology-sharing activities, and the TIP process proposed for the DOE are in order. The DOT strategy may be viewed as the strengthening of within-component technology transfer. We have asked whether it is necessary, since there are extant component linkages. The NASA strategy may be seen as a shotgun commercialization strategy. A vast resource is claimed to exist in NASA problem solutions. The NASA strategy filters these solutions by identifying uses for transportation and opportunities for commercialization. We may also ask if the NASA process is needed. Entrepreneurs exist in the private sector who screen possibilities and chase profits. In the presence of an existing mechanism, why create another?

The rebuttal to our questions about DOE- and NASA-technology transfer is that these are workable processes that can be made to work better: Within-component technology transfer works; private-sector technology transfer works. Technology-transfer programs represent efforts to make those processes work better, and their working better is surely desirable.

We can pose useful questions about TIP in the following way: What if TIP were applied to the NASA commercialization process (for components)? what if TIP were applied to the DOT within-component process? Diffusion mechanisms are strong in these two processes. Is the application of TIP necessary and can anything be learned from it? Suppose the process were applied to the needs identified by the TRB study of railroad research. We cannot guess the outcomes of these applications completely, but the TIP process would most likely identify as diffusible those research and test programs in which the industry is already engaged. A lack of diffusion, barriers, and a low payoff under present institutional and regulatory environments would probably limit management's interest in research and development to extant work.

CONCLUSIONS

We have characterized the supply and demand aspects of transportation technology. Needs are vast when they are broadly expressed as improvements in the functions or roles that transportation performs or might perform in society. Most commonly, however, needs are expressed in terms of reduced costs or of service responsiveness. The supply process is constrained by its disjointed, incremental properties. Individual component supply streams perform well, but there is little or no consideration of technology systems. These characteristics limit the effectiveness of rail technology programs and technology-transfer activities.

By extension of this finding to all transportation technology, the adequacy of supply processes is adversely affected by limitations in our thinking about transportation.

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Overview of the National Science Foundation's Intergovernmental Program

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The Intergovernmental Program of the National Science Foundation is designed to facilitate the maximum integration of scientific and technical resources into the policy formulation, management support, and program operation activities of state and local governments. This paper traces the evolution of the program from its inception in 1967 through the present time. The program began with an assessment of the scientific and technical needs of the executive branches of the states and the development of a community of interest in state and local governments, universities, industry, and other resource institutions that came together to develop the significant potentials for policymaking and operations that were apparent. The paper describes selected activities conducted with National Science Foundation support in the state executive branches as well as in the state legislative branches, local governments, and the federal laboratories, which have also emerged as major areas of program concentration. Significant changes have occurred during the period that the program has been in existence with regard to improved understanding and capabilities in state and local governments and the potential of science and technology as technical resource bases to assist in dealing with domestic policies and issues. Similar beneficial change has occurred in the way that state and local governments and resource centers relate to each other and to their noncounterpart institutions.

For about the last 10 years, the Intergovernmental Program of the National Science Foundation (NSF) has worked with other federal, state, and local units of government in an attempt to address the issue of disjointedness in our national system for science and technology.

The Intergovernmental Program became part of the foundation's Research Applied to National Needs (RANN) program in 1971. We are now being realigned into a new directorate, which is entitled Applied Science and Research Applications. In several ways the goals of TRB are close to those of our Intergovernmental Program. For example, TRB seeks to stimulate research and development on domestic-sector problems, it attempts to facilitate the dissemination of research outputs, and it strives to promote the application of research in a domestic setting. Our program at NSF is based on the premise that, although a great deal of technology (new ways of doing things, innovative methods) is being, and has been, transferred throughout such functional systems as transportation, a great many dysfunctions exist in our general institutional system insofar as how it might best facilitate the coming together of people who need new knowledge and people who have such knowledge. The Intergovernmental Program is designed to work with both ends of the spectrum—the user and the provider—to try to help maximize the input and the integration of new ways of doing things (i.e., new knowledge) into the decision-making and operational processes at state and local levels.

Science and technology, as defined in this small part of the NSF, is extremely broad. We deal with hard science, soft science, management science, and social science. Effectively, we deal with all sorts of new knowledge that may help state and local governments do their jobs.

COOPERATION WITH STATE EXECUTIVES

NSF's initial activities were undertaken in partnership with several state executive branches, generally with the governors' offices. During 1969-1970, a series of regional conferences and a national conference were conducted around the country by people from state government, local government, universities, private nonprofit research operations, federal laboratories and centers, and industry. They came together to talk about how, particularly at the policy levels in state government, the scientific and technological resources of the country could be better tapped to help the states deal with some of their problems and to help them improve their operations and policy-formulation processes. These were exploratory conferences and resulted in an extremely high degree of interest in all of these segments of the society to go further and to explore the potentials that existed in this area.

As a result of early interest, and, in particular, through a basic study of science and technology in state government, which was conducted by the Council of State Governments, a number of states began to try to develop new ways of strengthening their capacity to tap the scientific and technological resources available to them through such mechanisms as science advisors, scientific staffs, forecasting, planning, and operational analysis. NSF, with a relatively small amount of money, responded to these initiatives and provided some support for demonstration projects in California, Hawaii, New Hampshire, and Michigan. A high degree of interest was generated among the states during this period. For example, we began to work in considerable depth with the Council of State Governments, the National Governors' Association, and regional groupings of states, such as the Federation of Rocky Mountain States (now the Western Governors' Policy Office).

COOPERATION WITH STATE LEGISLATURES

We also recognized at an early stage that one of the parts of the system that needed better access to scientific and technological information was the state legislative community. A number of legislatures are not well staffed at this point, some do not meet for long periods in the year, and many have had limited access to technical resources. Since we have been involved with the legislatures, a trend has developed toward improvement and strengthening of the institution. We have worked with the legislatures to help them to develop further their in-house science and technology capabilities and to improve their relationships with the knowledge-generating community.

In an early cooperative project, the California legislature established a policy body that was technology-based. Their advisory council performed long-range studies in areas like nuclear siting and population policy. Wisconsin buttressed their legislative research staff with technically trained interns. That approach is becoming increasingly popular with state legislatures around the country. Illinois and Massachusetts have adopted science and technology-related intern programs, and Pennsylvania has coupled the six state-supported universities with the state assembly in a legislative office of research liaison. The Pennsylvania universities have committed themselves to providing answers to technologically related issues that face the legislature. In fact, at any one point in time, three faculty members from the participating universities are in residence in the state capitol to help the legislature and to relate to their campuses and to the others in the state for technical advice and assistance.

In the area of legislative information-sharing there have been many developments. For example, there is an association between a number of mission agencies like the U.S. Department of Transportation (DOT), the U.S. Bureau of Standards, the U.S. Department of Energy, the National Oceanographic and Atmospheric Agency, and the U.S. Environmental Protection Agency and the legislatures through the Model Interstate Scientific and Technological Information Clearinghouse (MISTIC), a science and technology information system that makes available to the legislatures the research outputs of these federal agencies. Also, the states are coming together now in an interactive way with a communications system through which they can exchange information on technological subjects. This eases the traditional problem of having 50 state legislatures working individually to reinvent the wheel. Issues dealt with include fluorocarbon regulation, pollution, and other environmental concerns. The legislatures are endeavoring now to develop a relationship with the Congressional Research Service (CRS) so that they can have access to the congressional computer and the extensive work that is done in abstracting and other services provided by CRS to the U.S. Congress. If this access is achieved, it could represent a significant breakthrough by opening up this important information base for the states.

Last year Congress passed the State Science Engineering and Technology Program, for which was authorized up to $3 million to provide funds to both state executive and legislative branches to help them assess

1. Where they are in regard to tapping science and technology resources,
2. How they could organize to do that better,
3. How they could improve their relationships with the resource bases, and
4. How they might begin to get better data on which to base decisions and to develop ways of providing services.

This program was mounted rather quickly, with the assistance of the National Governors' Association and the National Conference of State Legislatures. Executive branches in 49 states and legislative branches in 42 states received planning awards. At this point, no money has been provided for a full-scale implementation phase. Whether such funds will be forthcoming is problematical. But, nonetheless, the states will have gone through a beneficial exercise and, it is hoped, will be able to make improvements on their own, at least to a limited extent.

COOPERATION WITH LOCAL GOVERNMENTS

The focus for local governments is not on the transfer of individual technologies but, rather, on the disjointedness in the system and on the beneficial changes that might be achieved. Initially, a very few centers of activity, in terms of specific cities, were interested in new approaches in science and technology. Tacoma was a leader in moving ahead with the general issue of how to improve its capacity in science and technology. Philadelphia formed the Mayor's Science and Technology Advisory Committee. About 150 experts from industry, government, and the university community in Philadelphia joined as volunteers to support the mayor's efforts to deal with city problems. Four cities joined together in California with aerospace companies in the placement of technology agents in the city managers' offices to provide technology support. In Alabama, Auburn University took the initiative and established a capacity to support the cities and the states. Auburn has subsequently been joined by several campuses of the University of Alabama to form a consortium of universities to provide scientific and technological support.

At this time, there are a number of local government innovation networks around the country in the regions or states. The NSF's Intergovernmental Program provides a portion of the support of these groups. In California, the original 4 cities have increased to 11. There is a similar consortium of cities and states in the New England area, which is called the New England Innovation Group, and there are about seven or eight or more of these activities in various stages of development around the country. They are designed to try to facilitate the coming together of local governments to share the risk of taking an innovative venture, putting it to work in the individual cities, and facilitating the sharing process across the system.

At the national level, there are now three innovation networks of cities and counties. One of these, the Urban Consortium for Technology Initiatives, includes the 28 cities of more than 500 000 population in the country, and six urban counties. These jurisdictions united to develop research agendas that can be presented to federal mission agencies and others performing urban-related research. Another network of local jurisdictions ranging from 50 000 to 500 000 is called the Urban Technology System (UTS). In this network, technology agents have been placed in 27 cities and counties. This activity was originally a three-year experiment. We are in the process now of beginning to evaluate the effectiveness of this approach, which features the placement of technology agents in the cities to facilitate the implementation of new ways of performing the functions of local government.

The remaining national network is called the Community Technology Initiatives Program (CTIP). It is very new and includes local governments that have a population of not more than 50 000. Public Technology, Incorporated, which has a board of directors composed of representatives of the National League of Cities and the International City Management Association, is serving as the secretariat of these networks.

CONCLUSION

An interesting resource base for technological assistance to state and local government is the Federal Laboratory Consortium for Technology Transfer. This consortium is composed of about 180 laboratories, which represent 10 federal agencies. Each of the laboratories has designated a technology-transfer coordinator to serve as contact point for the consortium to facilitate sharing of technology information among the laboratories and agencies and to persons in industry and in state and local governments.

The efforts of NSF in working with state and local governments could not have been as successful as they have been without the cooperation of the federal agencies that are testing and using some of the networks and other mechanisms that have been developed for strengthening governmental capacity and for technology transfer to our state and local governments. Progress has been made in heightening the awareness of policymakers and top administrators at federal, state, and local levels of government with regard to the potentials of better use of the country's science and technology resources in dealing with domestic issues. Mutual interests have been highlighted and linkages have been developed. Also, beneficial changes have been achieved that will never disappear.

Overview of Federal Programs and Activities

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A general overview of technology-transfer activities of federal agencies is provided in this paper. Major emphasis is placed on factors and processes that appear necessary for successful transfer programs. U.S. Department of Transportation policy and activities are highlighted as examples of ways in which technology, including hard products, processes, and knowledge, can be transferred for greater utilization in the public sector.

There is now a great deal going on in the area of technology transfer at the federal level. It is rather heartening to those of us who have been in the business for quite a few years. I would like to first define what I mean when I talk about technology transfer. There are many phrases used to describe such activities. For example, we call our program technology sharing. The classical definition for technology transfer has really been associated with spin-off or secondary applications, that is, where you take a technology developed for the National Aeronautics and Space Administration (NASA) or the U.S. Department of Defense (DOD) and try to apply it to another sector, such as transportation, health, education, or other private sector. The federal government looks at technology transfer from a much broader definition, trying to get products, processes, knowledge, or whatever results from research, development, and demonstration programs, applied and used in the public or civil sectors. My definition encompasses secondary spin-off, but also includes the case where we are trying to transfer from the federal level to the state or local level, in a specific mission area, such as is the case in the U.S. Department of Transportation (DOT). Basically, the purpose is getting the products out and used. It has become a very important subject, and one of the reasons for this is because of fairly extensive interest from state and local governments and an expressed concern that a great deal of money was being spent at the federal level on research and development that had very little benefit to the public sector.

Although one could argue that numerous benefits accrued to the public sector, there was not enough emphasis on transfer. The concerns were also logical when one considers that from 1966 to 1976 the federal government spent $185 billion on research and development; a majority of that was for defense and space. NASA and DOD have their primary missions; their research and development is for products for their own use. But, even during that 10-year period, $50 billion was spent on research and development for the civil sector. What has resulted from that expenditure in the way of useful products for state and local governments and the public and private sectors? Such questions are being asked, and I believe an increased emphasis on technology transfer can help ensure positive answers.

The National Science Foundation (NSF) has been a leader in trying to establish mechanisms for the process of technology transfer. The disjointedness of technology-transfer activities is being addressed by many of the NSF programs. Other agencies are doing different things. Some agencies are moving aggressively in this area, others are not moving as rapidly. This paper will talk about some subtle key factors that will make or break the success of technology transfer, both now and in the future. If we look at some programs that have been successful in this area, I think some of these factors will become evident.

As an important aside, if you are interested in the technology-transfer activities of various federal agencies, there is a document titled the Directory of Federal Technology Transfer (1). This document summarizes the activities of some 40 agencies of the federal government in the area of technology transfer.

The factors I will cover are the following:

1. A commitment to technology transfer;
2. The rewards for people doing or trying to achieve technology-transfer successes;
3. Understanding of the intended users and tailoring of products and information for them;
4. User involvement throughout the process, not only at the end;
5. Public and media acceptance of technology transfer (which is really the acceptance of research and development or science and technology); and
6. Expectations that we and others might have on achieving successful technology-transfer programs.

COMMITMENT

The achievement of anything of significance and substance generally requires commitment. This is especially true in a relatively new field of emphasis (technology transfer is in this category for most agencies). Ideally, the commitment has to permeate the entire organization responsible for the area of interest. You can have an individual in the bowels of an organization who is totally dedicated and committed to technology transfer as the critical element in the process of solving problems, but if there is no commitment on the part of his or her superiors to the same objective, he or she will have a hard time getting support for such activities (support meaning budgets and time to devote to the activities). Unfortunately, up until recently, the above scenario has been the rule. That is, commitment for such activities was not coming from the higher levels but rather from midmanagement and working levels. There are, of course, exceptions to this rule and, additionally, the recent signs of change indicate that commitment to technology transfer is reaching the highest levels.

One major indication at the federal level is reflected in the National Science and Technology Policy, Organization and Priorities Act of 1976 (P.L. 94-282). The act establishes a science and technology function within the executive branch by law, rather than previous precarious functions and associated offices that were at the whim of the President. The act has numerous references to technology transfer, information dissemination, and utilization.

The Intergovernmental Science, Engineering, and Technology Advisory Panel is most active at this time. The panel is composed of state and local elected officials. The chairperson of the panel is the President's science advisor, Dr. Press (also Director of the Office of Science and Technology Policy), and the vice-chairperson is George Busbee, governor of Georgia. The basic purpose of the panel is to provide state, local, and regional input and advice to federal science and technology (research and development) policy and decision making.

The panel has structured itself into five task forces, all of which are active, and the panel and all task forces have a major emphasis on technology and knowledge transfer. Panel members have met with some cabinet officers and high-level policy officials and have received strong indications of support for the panel activities and concerns from the President and various federal departments. I conclude from all this that the commitment to technology transfer, broadly defined, is developing at high levels of the federal government and that, because of this, commitment will eventually show up or be endorsed and supported at all levels. This in turn will influence, in a supportive fashion, commitment to technology transfer in universities, industry, and other levels of government.

Such commitment should help relative to another important consideration, that is, rewards.

REWARD STRUCTURE

Within the research and development community, rewards are based on doing or managing good research as measured by other researchers. The "publish or perish" philosophy in universities is also of this nature; that is, you are judged by your peers. Fortunately, I see many changes away from strict adherence to this philosophy, but we have a long way to go. It takes extremely dedicated people to concern themselves with whether or not the results of their efforts are being applied to real-world problems when the reward structure does not recognize such activities as being important.

To emphasize this point, I might ask the question, "How many heads or top policy officials of science and technology or research and development organizations or universities have been elevated to their positions as a result of a career dedicated to technology transfer?" Also, there are prestigious awards, such as Nobel prizes, for all types of scientific achievements in various fields. It seems time to have prestigious awards for great achievements in technology transfer. After all, in the final analysis, only after the technology (or product, process, and knowledge) is applied for the benefit of mankind does it have any real significance. I want to make clear that in no way am I advocating rewards in this area at the expense of rewards in the basic science and research areas. These must continue in order to ensure that the pipeline of new knowledge, products, and processes is always full and flowing. One system that has been the exception to the rather grim picture (for technology transfer) I have painted, is the agricultural research and associated Cooperative Extension Service, for which one will usually obtain unanimous agreement that it is the most successful program of technology transfer ever structured (or evolved). There are numerous reasons for its success, but I feel one of the more significant is that the reward structure was based on the transfer and application of the developed knowledge. A researcher's success was measured in terms of transfer.

Changes are occurring, but much more active attention needs to be given to ensuring that people working in this area are rewarded, through prestigious awards, monetary and position increases, and recognition. Human nature is such that this alone will significantly enhance the field of knowledge transfer to the benefit of all, in that more and better transfer will follow.

USER UNDERSTANDING AND TAILORED KNOWLEDGE

In effectively transferring technology we need to know what factors are important to the user (and potential implementor) of the technology. If our objective is to transfer research or scientific knowledge to another researcher or scientist, then standard, scholarly, scientifically precise research documents are valid and necessary. But many research documents that are intended to provide the answer to some specific real-world needs or problems are sitting on shelves gathering dust. Many of these documents do in fact contain some of the answers; however, the real user (that is, the person or persons who will decide whether to apply the technology) cannot understand the document. It may be too complex and scientific, and the implications for his or her decision criteria may be too obscure or not addressed.

Complicating this is that in essentially all situations there is more than one decision to make, and their language, decision criteria, and technical sophistication vary across a wide spectrum. There are two generic groupings at the state and local levels; one is general-purpose oriented and the other is function or mission oriented. Although, in general, the federal government has been structured and programs have been established along functional lines, the elected and appointed officials (through their own initiative and through changes in federal legislation and procedures) are taking increased responsibility for decisions that quite often in the past were handled directly between federal and state or local functional organizations.

Within any given area of interest, such as transportation, technology and knowledge must be provided to a series or group of decision makers, each of whom may judge the application of the technology from a different perspective. What all of this means is that knowledge on one subject must be packaged in different forms, often with different levels of detail and sophistication.

We try to involve representatives from the intended user group in the development and finalization of the document. This does two things: First, it ensures that the right kinds of information and level of detail are provided; and second, it results in a much higher degree of acceptance by the entire user community because their peers have been involved in its development. A lot of free and enthusiastic advertisement results from this approach. User involvement, however, should not be restricted to only the final stages of the transfer process.

USER INVOLVEMENT

One of the problems with much technology transfer is that it ends up being very much a push process. That is, a researcher or research organization will work long and hard on some process or product that it feels will have some benefit to a user community. However, there will be no contact with the user community until the person or persons wanting to transfer the knowledge come in and unveil their elaborate reports and briefings, stating, "I have the solution to your problem." Receptions to this approach obviously vary, but more often than not they tend toward the range running from skepticism to "get this snake-oil salesman out of here."

I believe such reactions are both to be expected and reasonably justified. If the user has not been involved at all up to the point of revelation it is unlikely (a) that he or she will feel that you really understand the problem or the institutional difficulties in implementing solutions, (b) that the important decision factors for the specific user have been considered and covered, and (c) that the feeling of trust necessary for effective and efficient transfer will have been established.

It has been shown that the most widely accepted successful transfer programs are those that involve the user from the identification of specific needs and problems, through the structuring and conduct of the research (or whatever is necessary for solution) to the packaging and dissemination of the process or product. The agricultural process was of this nature as is the cooperative highway program of DOT and the states.

PUBLIC AND MEDIA ACCEPTANCE

My fifth point has to do with acceptance by the public of the importance of technology transfer, which will most likely be manifested in the importance of the programs that generate the technology. I believe it would be difficult to distinguish between the two in the eyes of the public.

I have begun to conduct an unscientific, ad hoc, personal survey relative to public perception of science and technology. I have two questions I ask. The first is, "When I say the words science and technology, what is the first thing that comes to mind?" After an answer to that question, I ask, "Do you feel science and technology have done anything for you?" As you can imagine, I have received some interesting answers. As one example, I asked these questions of a stewardess while flying cross-country. Her answer to the first question, after much thought, was "chemicals." Her answer to the second question was an emphatic "no." Here we were flying at 12 190 m (40 000 ft), at 965 km/h (600 mph), she wearing her outfit made of synthetic fabrics, having just served meals from microwave ovens, and the answer is no. If I had added the question, "Do you think it is important that we have programs to ensure the transfer of scientific and technical knowledge?" I think we would all agree on what the answer would have been.

If we want to cause a change in this regard, we obviously need to consider the news (and possibly entertainment) media. Disaster movies are the rage now, and, of course, the news media has operated on this same principle for some time. Crime, problems, and failures make the headlines. After a number of years of successful operation, the Bay Area Rapid Transit system, which incorporated some of the latest and best design and technical features, is still primarily remembered for the time, in the first months of operation, that one of the cars ran off the end of the track due to a malfunction in the automatic control system. I could give many other examples, but I am sure I need not convince you that failures make the news.

I do not have a prescription for how to solve this, but I believe it generally involves a greater effort on our part to make friends with the media, help them to understand the benefits of technology transfer and perhaps the benefits to them of reporting such. Perhaps we need to stimulate or sponsor the development of special public-oriented newspapers and magazines.

EXPECTATIONS

Emphasis on technology transfer is growing at all levels of government, and at the federal level in both the executive and legislative branches. A major new program, for example, is the U.S. Department of Energy (DOE) Energy Extension Service (EES), which was established based to a large extent on the success of the Agricultural Extension Service. Great things are expected from the DOE-EES. However, the top-level officials in government must be cautious of expecting dramatic success overnight. The agricultural program started some 60 years ago; the Federal Highway Administration program, which is also a highly successful technology-transfer program, has a comparable age. It took a great deal of work and time with small successes following one another until, after some time, the overall programs could be viewed as a success.

We need to work as hard as we can, but we must also temper our, and others', desires to get problems solved immediately with realism in terms of how long it can take to achieve success.

CONCLUSIONS

Effective technology transfer is crucial to meeting needs and solving problems. It is also a difficult and complex process for many reasons encompassing human, organizational, institutional, technical, and other factors. There is a growing body of literature, experience, and knowledge on this subject. I have tried to address what are perhaps the more subtle (but I believe critical) aspects that, in the final analysis, will make the difference in establishing technology transfer as a broadly supported and highly esteemed field of endeavor. My hypothesis is that this is necessary to obtain the major beneficial impacts that I feel technology-transfer efforts can provide. We need to keep these considerations (commitment, rewards, tailored knowledge, user involvement, public and media acceptance, and expectations) in mind as we proceed to emphasize and improve technology-transfer activities and programs.

REFERENCE

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Federal Laboratories–A National Resource

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Many of the social and economic problems that face our country could be solved by technology and expertise that exists or is being developed in federal laboratories. An effort is under way to make federal government scientific and technological resources available to other federal agencies, to state and local governments, to colleges and universities, and to private industry. An informal Federal Laboratory Consortium for Technology Transfer exists to coordinate the exchange of technology and expertise among these various agencies. The organization and operation of this consortium are described, and suggestions are given for making it more effective in serving the technology needs of the nation.

The significant investment this country has made in research and development, if properly adapted, could greatly contribute to the resolution of many of the problems of state and local governments. A current effort is under way to make available to state and local governments the vast science and technology resource available within the federal laboratories. This paper describes the Federal Laboratory Consortium (FLC) for Technology Transfer, of which I am chairman. Its major objective is the transfer of expertise and capability existing within these federal laboratories to help solve problems in the public and private sector.

NATIONAL INTEREST DEMANDS OPTIMAL USE OF TECHNOLOGY

A multitude of technical as well as social and economic problems faces our nation. If our standard of living is to remain at its current high level, we must pay immediate and serious attention to such problems. Among the more important national concerns that face all levels of government today are the energy crisis, unemployment, and high prices. An overabundance in some areas and deficiencies in others provide the fuel for continued unrest and uneasiness in the minds of many public officials and citizens. Rapid changes in public needs and private wants have brought about critical intergovernmental issues. The costs associated with addressing these problems can be extremely high. In many instances, use of technology that may exist but has not yet been applied is required.

State Government Problems

I would like to give you some examples of the kinds of problems faced by local governments. For instance, the technology-transfer coordinator for Oregon asked for help on several problems currently faced by Oregon. First, several cities in Oregon now use salt as a de-icing agent, but they would very much like to know of any alternative methods now being used by others. Second, the Oregon Public Utilities Commission is attempting to determine the effect of wind on railroad warning signs and lights. Having access to a wind tunnel would be most useful in providing reliable data. Finally, he mentioned a problem noted because of the collapse of a small state-owned bridge. The bridge collapsed because the wood pilings that supported the bridge had been eaten through by marine borers that are not detectable by the casual observer. The Oregon State Highway Department now must find a method of determining the structural soundness of all other state-owned bridges supported by wood pilings. To do an operation of this kind manually could cost the state several million dollars a year.

Cooperation Among All Technology Sectors Essential

Every available science and technology resource must be tapped if timely solutions are to be found to the nation's problems. The problems are complex and will require partnerships between state and local governments, the federal government, industry, and universities. No one sector can provide all the answers. Industry, which operates on a profit motive, can satisfy the wants of the average citizen, but what about the needs of state and local governments? The likelihood of industrial solutions to the problems of local governments appears minimal due to the lack of a developed and aggregate market. In general, our colleges and universities also are not designed or intended to offer the total spectrum of technical resources required to respond to problems of these government entities. Our federal government laboratories contain a large national investment in scientific facilities, equipment, capabilities, and experience. These laboratories, when properly mobilized, could possibly provide the solutions to many of our nation's problems.

FEDERAL GOVERNMENT LABORATORY RESOURCES

During the past decade, the federal government has spent more than $200 billion for research and development. Approximately $24 billion was spent in fiscal year 1977 for research and development purposes. Plant expenditures for research and development facilities and equipment were expected to reach approximately $4 billion during fiscal year 1977. These monies represent an investment made by each federal taxpayer. Not all federal government research and development funds are spent intramurally; a very large percentage is spent by the private sector. However, a good portion of these funds is invested each year in the federal laboratories. In fiscal year 1977 alone, these federal laboratories spent $6 billion on research and development.

The latest report on federal laboratories indicates that there are well over 700 federal laboratories and centers located throughout the nation. They represented, in 1972, a work force of 260 000 people and an intramural research and development budget that approached $7 billion. Over the years, a sizable amount of technology has been developed that could be adapted to help solve some of our country's problems. However, in many cases, no deliberate or active effort has been made to take full advantage of the problem-solving potential of existing and emerging technology.

The numerous federal laboratories can be segregated into three major categories:

1. Mission agencies that require high technology to develop equipment and other capabilities to meet national objectives, such as the U.S. Department of Defense (DOD);

2. Mission agencies that have an intrinsic requirement to work with other government agencies (federal, state, and local), such as the U.S. Department of Transportation (DOT); and

3. Federally funded research and development centers that are not part of the federal government but operate under federal funds. For example, the national laboratories operate under contract to the Energy Research and Development Administration. However, this type of laboratory is subject to different guidelines than are federally owned and operated laboratories.

SHARING FEDERAL TECHNOLOGY

There is one dominant justification for making the technical resource represented by the federal laboratories available to state and local governments: A greater return can be had on the taxpayer's investment in science and technology through more effective primary and secondary use of research and development results. State and local governments are aware that many of their problems can be solved only through the use of science and technology; however, these agencies cannot afford to invest large sums in research and development. Federal government laboratories may not have the technology to solve all the problems of these other government agencies, but substantial public investment in research and development has been made, and technologies do exist and are being developed that could fill important gaps.

If the productivity of state and local governments can be increased through use of these federal laboratories, industry, acting as the commercial link in the process, can also benefit from an expanded role of the federal laboratories. These laboratories can offer a large amount of technology that is not currently or widely available in the private sector and, if this technology has commercial potential, a transfer may prove economically possible.

FLC AS MEANS FOR SHARING

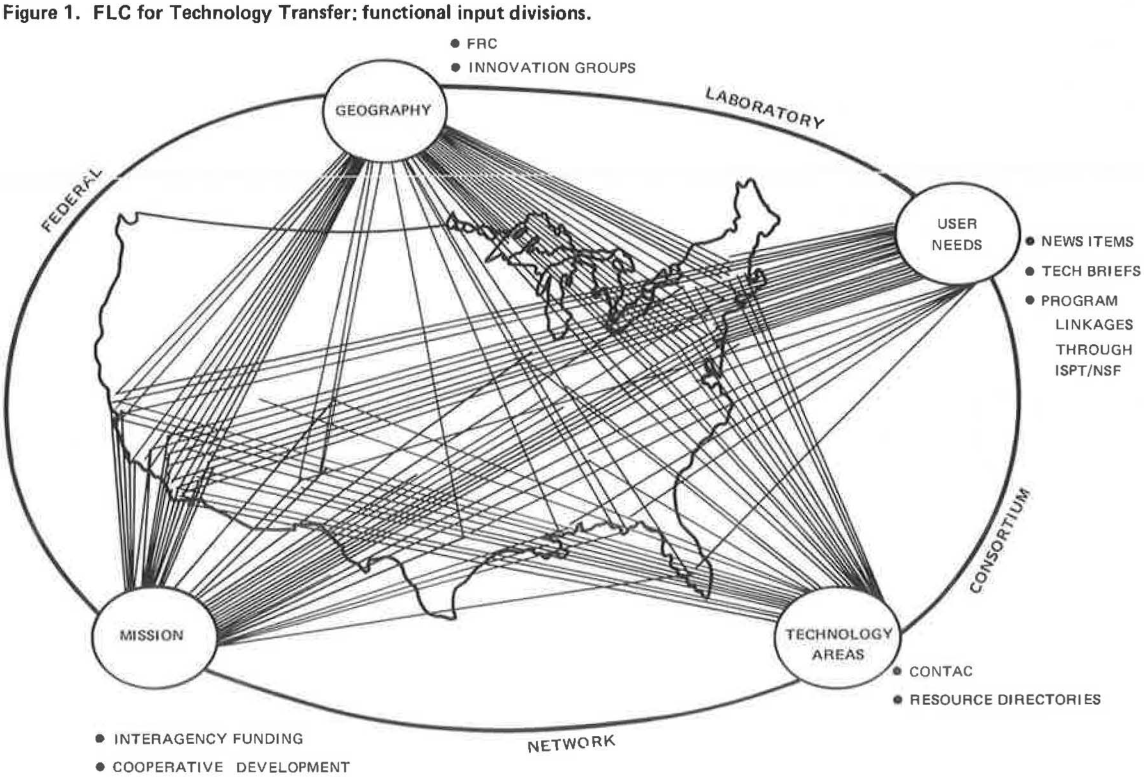
The next question is, How can the resource represented by these laboratories be made available? Federal laboratories are accountable to many federal government agencies, and no formal integrating management system exists within these laboratories to ensure that the technology transfer and utilization process is coordinated and productive. There is, however, an informal FLC for Technology Transfer that currently consists of more than 150 of the largest federal government laboratories and centers representing a number of high-technology agencies.

The consortium is decentralized and can respond to virtually any technological problem. Clearly, the laboratories in this system represent the complete spectrum of federal research and development activity and are a national resource for assistance to state and local governments. The task ahead is to implement the FLC as a science and technology delivery system that can effectively coordinate and make use of these capabilities in the national interest and for the public good.

Beginning and Growth of FLC

The consortium actually had its beginning in the summer of 1971. At that time 11 DOD laboratories met at the Naval Weapons Center, China Lake, California, to determine common methodologies in finding greater uses for technical knowledge developed for military purposes. These 11 laboratories formed an informal affiliation called the DOD Technology Transfer Laboratory Consortium; it currently consists of 45 members. In November 1974, these and all other federal labora-

Figure 1. FLC for Technology Transfer: functional input divisions.



tories were invited to join a FLC for Technology Transfer that was patterned after the original DOD affiliation. FLC membership currently consists of 154 laboratories, represented by 76 technology-transfer coordinators within nine federal agencies. This informal organization represents a technical work force of approximately 100 000 people, a national investment of at least $6 billion, and an annual expenditure of nearly $4 billion.

Table 1. Technology areas researched by major FLC laboratories.

Technology Area	Contact
Atmospheric sciences technology	National Aeronautics and Space Administration (NASA)-Wallops Flight Center
Biomedical technology	Harry Diamond Laboratory
Business administration practices	Army Construction Engineering Research Laboratory
Communications	Naval Ocean Systems Center
Computer technology	NASA-Lewis Research Center
Construction technology	Army Construction Engineering Research Laboratory
Cold regions	Army Cold Regions Research and Engineering Laboratory
Detection	Army Night Vision Laboratory
Electrotechnology	Air Force Avionics Laboratory
Energy	
Alternatives	Los Alamos Scientific Laboratory
Solar	Lawrence Livermore Laboratory
Geothermal	Lawrence Berkeley Laboratory
Nuclear	Los Alamos Scientific Laboratory
Fire	Naval Weapons Center
Food sciences	Food Sciences Laboratory-Natick R&D Command
Hazardous materials	Chemical Systems Laboratory
Human resources research and development	Navy Personnel R&D Center
Investigative procedures	Federal Bureau of Investigation Laboratory
Law enforcement	Naval Ocean Systems Center
Library and information sciences	Naval Ocean Systems Center
Navagation and guidance	
Air	Air Force Avionics Laboratory
Water	Coast Guard R&D Center
Nuclear technology	Los Alamos Scientific Laboratory
Ocean technology	Civil Engineering Center
Ordnance	Naval Explosive Ordnance Disposal Center
Pollution	
Marine	Coast Guard R&D Center
Water and air	Chemical Systems Laboratory
Remote sensing	NASA-Ames Research Center
Standards science	National Bureau of Standards
Telecommunication	Institute for Telecommunication Sciences
Transportation	Transportation Systems Center
Urban & regional technology	Naval Underwater Systems Center

The basic objective of the FLC is to design, develop, and implement, on a systematic basis, mechanisms that facilitate the application of unique mission agency federal laboratory capabilities to nationally defined problems so that publicly funded research and development resources are made widely available on a cost-effective and timely basis. Special emphasis is given to problems associated with the intergovernmental use of federal laboratories and centers for the solution of domestic problems at state and local government levels.

Operation of FLC

FLC operation is aimed at eliminating, or at least minimizing, the effects of a multitude of barriers and constraints that hamper the technology-transfer efforts of the federal laboratories. The FLC emphasizes person-to-person communication between the civilian sector users and the resource people in the federal laboratories. The core activities of the FLC include:

1. The development of a well-organized information system,
2. The continuous involvement of the users in the problem definition and technology-transfer phases, and
3. The discrete use of linking agents or technology-transfer brokers to bridge the communication gap between researchers and users.

The most important part of this federal laboratory network is its method of operation. The most obvious question when one looks at the federal laboratory system is, How can anyone interface effectively with such an immense and diverse resource? Regardless of whether you are a federal, state, or local government user, or industry, or another laboratory, the interface is extremely complex. Figure 1 is a conceptual schematic of this network according to divisions. The diagram is an attempt to show that there are some reasonable mechanisms to the entire network that make laboratory technology more accessible.

The four divisions on the periphery of the ellipse

Figure 2. FLC regional divisions.

are geography, user needs, mission, and technology areas. The mission division is a traditional mission agency notion (i.e., DOT laboratories respond to transportation needs and DOE laboratories respond to energy needs). Obviously, inputs are made to the system through the mission division, but, for technology transfer purposes, they may not represent the best entry because other agencies often have technical activities similar to those found in a mission agency.

Within the FLC is a technology area coordination system for contact for technological application coordination (CONTAC) that attempts to cut a cross section of the laboratories in terms of technology areas. Many technology areas currently identified with certain laboratories can be seen in Table 1. A resource directory is available that allows a user, whether public or private, to find out what is generally available in the laboratory system. Interestingly, no directory addresses the total spectrum of capabilities within the laboratories.

The user-needs division is an input mechanism that attempts to make the federal laboratory system aware of the needs of potential users. One mechanism currently used is a monthly FLC newsletter that makes user requirements known to consortium representatives. This and other planned efforts are combined with program linkages to the public sector implemented through the Intergovernmental Science Program at the National Science Foundation (NSF).

The geographical division is a regional network designed to aid state and local governments more directly (Figure 2). Within each FLC region, the laboratories maintain a close working relationship with the existing NSF intergovernmental activities previously mentioned. These regional activities form a technology-transfer network. If a person in a state or local government has a problem, he or she can interact with someone locally and not become too involved in the national network unless there is some overriding reason that makes it necessary to do so.

CONCLUSION

To use all available resources to solve national problems, there must be greater interaction and communication between the federal laboratory system and local levels of government, as well as with the private sector. The federal laboratory system is an important public investment, and only time and dedicated effort will tell if this system, when viewed as a national science and technology delivery system, will be successful.

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The opinions or assertions contained herein are mine and are not to be construed as official or reflecting the views of the Department of the Navy.

Federal and State Programs and Activities for Transportation Technology Transfer

Milton P. Criswell, Federal Highway Administration

This paper describes some of the technology-transfer programs and activities within the U.S. Department of Transportation (particularly those of the Federal Highway Administration) and state transportation and highway agencies. The U.S. Department of Transportation programs highlighted include the Technology Sharing Division and Transportation Research Information Service of the Office of the Secretary, Transportation Systems Center activities, Urban Mass Transportation Administration planning systems, and major research, development, and demonstration programs. The technology-transfer programs of the Federal Highway Administration described include details on research implementation, experimental projects, demonstration projects, and National Highway Institute programs and the internal-technology-transfer delivery system established to conduct this function. Some of the principles and successful approaches being used by state highway and transportation agencies to conduct effective technology-transfer programs are also described.

From its beginnings, the U.S. Department of Transportation (DOT) has devoted major attempts to technical assistance with associated dissemination of results of research, development, and demonstration programs to states and cities. Most directly concerned with the subject of technology transfer are the specific research, development, and demonstration programs conducted in the Office of the Secretary and within the operating administrations. I will not attempt to go into detail on the many technology-transfer activities of DOT; however, I would like to highlight some of the more important ones.

OFFICE OF THE SECRETARY

The Office of the Secretary (OST) Technology Sharing Division is active in the technology-transfer efforts on a governmentwide basis. The efforts of Al Linhares, in particular, have been significant in the organizational and ongoing efforts of the Urban Consortium Transportation Task Force and the Committee on Domestic Technology Transfer, a coordinating body for civilian federal agencies, which is sponsored by the Federal Coordinating Council for Science, Engineering, and Technology. In addition, a Transportation Research Information Services (TRIS) network is being developed in OST to link transportation information service centers in a system to provide one-stop service of the information needs of transportation-oriented technologists and planners. Individual DOT-sponsored information systems, such as the Highway Research Information Service

(HRIS), are the building blocks for the TRIS network.

RESEARCH AND SPECIAL PROGRAMS DIRECTORATE

The new Research and Special Programs Directorate includes the Transportation Systems Center (TSC) in Cambridge, Massachusetts, a major research arm of the DOT, which has a large role in the exchange of information with states and cities. TSC's basic roles in technology transfer are (a) packaging and disseminating research results, (b) conducting training courses and seminars, and (c) giving technical focus to OST-supported activities in the transfer process. The center is also responsible for maintaining and updating the TRIS file to ensure that these files are available to the state and local community.

The directorate also includes the following:

1. The Transportation Safety Institute in Oklahoma City, which provides safety training courses for state and local government and industry respresentatives;
2. The Materials Transportation Bureau, which provides training in accident investigations, hazardous materials safety, and inspection techniques for state and industry representatives; and
3. The Universities Research Program, which is designed to focus universities' expertise and knowledge on the solutions of pressing national transportation problems.

URBAN MASS TRANSPORTATION ADMINISTRATION

Technology transfer has always been inherent in the Urban Mass Transportation Administration's (UMTA's) operations because of its large grant and assistance program.

The UMTA Urban Transportation Planning System (UTPS), part of a joint UMTA-Federal Highway Administration(FHWA) developed multimodal software planning package, provides state and local planners with the latest technology in transit planning tools to assist them in solving their local transit problems.

UMTA's major research and development programs cover subjects such as bus and paratransit, rail transit, new systems and automation, safety and product qualification, and socioeconomic factors. The delivery system for using the technology developed in these programs is built-in and supported by UMTA operating programs. For example, the light rail program is designed to provide guidelines and standards for low-cost urban light rail vehicles and systems. The Office of Research and Development is generally responsible for the research and development and initial field test and evaluation of the developed hardware. UMTA's demonstration programs are then used to fund, promote, and obtain widespread use of the new technology on a trial basis. As part of its training program, UMTA is developing resident courses for transit system managers.

UMTA's dissemination activities are designed to ensure that program results are documented and readily available and that the information generated is in a form readily assimilated by the transportation community.

FEDERAL RAILROAD ADMINISTRATION

The Federal Railroad Administration's (FRA's) current technology-transfer efforts are oriented toward the near and intermediate requirements of railroads, railroad equipment suppliers, state and local governments, and areawide planning agencies.

The major test facilities for FRA research and development are at the DOT's Transportation Test Center near Pueblo, Colorado.

NATIONAL HIGHWAY TRANSPORTATION SAFETY ADMINISTRATION

The research and development and technology-sharing efforts of the National Highway Transportation Safety Administration (NHTSA) are oriented toward three major program priorities:

1. Safer vehicles for occupants,
2. Alcohol countermeasures, and
3. More effective vehicle standards.

Technology-sharing efforts are fostered by governors' highway safety representatives, national advisory groups, demonstration programs, information services, and training programs. NHTSA offers a resident course in Highway Safety Program Management at the Transportation Safety Institute.

FHWA

Technology transfer is a major program element in FHWA, and many believe it is the key to the continuous success of the highway program. One of the most significant points FHWA has recognized is that technology transfer can no longer be left to chance, goodwill, or coincidence. It must be organized, maintained, and managed. Accordingly, all levels of the FHWA have a role in FHWA's technology-transfer activities. In Washington, at the top-management level, an executive committee on application of improved technology has been established to coordinate the overall agency technology-transfer activities. At the middle-management level, an interoffice review group has been established in headquarters for the four Washington-based programs involved in technology transfer to coordinate their activities and to prevent duplication of effort.

These four programs are

1. The Implementation Program in the Office of Research and Development,
2. The Experimental Projects Program in the Office of Engineering and Traffic Operations,
3. The educational program of the National Highway Institute, and
4. The Demonstration Projects Program in FHWA's Region 15.

The Implementation Program includes full-time professional engineers, known as implementation managers, who are responsible for translating research into a form suitable for practice. The translation includes appropriate field testing and evaluation and the development of operating tools or user packages generally consisting of some combination of field orders, manuals, handbooks, specifications, films, training materials, computer software packages, and prototype hardware necessary for successful technology transfer. The implementation managers establish and maintain relationships with appropriate FHWA research and Washington office personnel, who together work as a team during the transition period when a product moves from research to practice.

The Experimental Projects Program provides the means by which field tests and evaluation of new highway construction materials, equipment, and processes that have a high priority for application can be achieved.

Through the Demonstration Projects Program, opportunity is provided for states to observe actual field demonstrations, which show the practical application of new technology resulting from research and development. The National Highway Institute programs provide the mechanisms for necessary educational and training programs that are essential to the adoption of new and improved technology.

In the FHWA field organization, regional technology-transfer coordinators have been established as the focal point for regional efforts to promote and stimulate the potential application of appropriate new technology in their regions. At the state level, each FHWA division office has given designated individuals the responsibility for technology-transfer activities similar to that at the regional level. The FHWA division offices provide the primary focal point for FHWA efforts in reaching states, cities, counties, and other local users. In fiscal year 1976, to emphasize its importance within the agency, FHWA designated technology transfer as a major program emphasis area. This served not only to stimulate technology-transfer activities within FHWA, but to firm up the necessary delivery mechanisms required for a successful activity.

STATE HIGHWAY AND TRANSPORTATION AGENCIES

The American Association of State Highway and Transportation Officials (AASHTO) Special Committee on Utilization of Research, in a study completed in 1968, highlights an unnecessary and undesirable lag between completion of research and the utilization of findings from highway transportation research. The committee concluded that the lag was caused by a communication gap or missing link between research and operations. Active state technology-transfer programs start with the objective of bridging this gap as a foundation of its efforts. The AASHTO committee also indicated that the gap might be bridged by a new breed of professional generalists. Today, we would probably identify this generalist as a technology-transfer coordinator.

A practice of involving operational personnel, who are the potential users in the decision-making process for the technology under consideration, is the most commonly used mechanism in states that have active technology-transfer programs. This involvement starts with the screening process and proceeds right through whatever experiments or trials are deemed appropriate, to the point where a decision can be made to accept (even partially) or reject. In many states the initial involvement starts with research and operations representation on a research, implementation, advisory, or user committee, or some ad hoc group that does not have a specific title. Quarterly (or periodic) and final meetings are normally part of the monitoring phase prior to final decisions for those items that require field trials and evaluations. When the decision is made to accept, classroom training, workshops, or seminars have key roles in the way states attempt to achieve widespread application in the desired manner.

One effective technique used by a state to involve operating personnel early in the review process for technology developed elsewhere is to screen the projected outputs of FHWA implementation efforts with the FHWA division technology-transfer coordinator to determine which items might have the greatest application for that state. State functional specialists are then selected to monitor designated items. This technique has the advantage of providing lead time if additional resources are required, spreading the work load, and providing a management framework for the large number of items under consideration at any one time.

Most states conduct excellent in-house training by using their own personnel. There is substantial technology, however, that requires assistance by outside resources. The FHWA National Highway Institute programs are active in this area. In addition, states have working arrangements with their own state universities and colleges to provide supplemental training without going outside the state. This is particularly important in view of current restrictions on out-of-state travel. In some cases this training has been accomplished by using material produced by FHWA, which is available free of charge. Carrying the training process one step further, some states have programs that allow city and county personnel to sit in and receive training along with state personnel.

An effective transfer mechanism, which is increasing in popularity, is that of states allowing their personnel to take active roles in providing training outside their boundaries. Good examples of this are the participation of personnel from

1. Wyoming—computerized bridge rating system,
2. California—air and water quality,
3. Texas—safety programming, and
4. New York—wave equation.

Also, state efforts in the preparation of implementation packages and other user-oriented materials have increased substantially during the last few years. Good examples of the activity are

1. Georgia—Portland cement concrete pavement finishing,
2. North Carolina—production management for maintenance,
3. Texas—quick load test,
4. California—water quality manuals,
5. Oregon—keyed rip-rap film,
6. New Jersey—Stimsonite 99 slide tape,
7. Utah—preformed inductive loops, and
8. Nevada—finishing of concrete structures.

In some states, effective use has been made of the implementation line item on activities, such as preparation of implementation packages and visual aids, conduct of seminars, workshops and demonstrations, and evaluation of experimental projects.

Most states have instituted activities, such as informal one-page flyers or newsletters, short unofficial films or video tapes, and slide packages, for field distribution. Some states prepare annual research implementation accomplishment reports. These activities supplement other more formal practices, such as issuance of directives or changes in specifications or standards.

A very significant technology-transfer activity involves the substantial number of new proprietary products that are introduced annually for application on the highway system. A cooperative AASHTO-FHWA effort is to consolidate all test and evaluation information from the states testing those products and to issue the publication Special Product Evaluation List (SPEL) (1).

Complementing the more formal technology-transfer activities are national and regional groups, which meet periodically to exchange information on new technology. For example, the states in Region 3 have held periodic meetings for the last few years on regional bridge deck deterioration and exchanged their experience with potential solutions. Joint state-FHWA regional meetings over the years have included technology transfer as major items on their agendas. Probably the most important information groups are the committees supported by larger organizations such as AASHTO and TRB. All these informal group activities provide the essential communication networks that fill the gaps in information exchange left undone by the more formal efforts. In accomplishing the described state activities, federal resources from programs such as the federal-aid, demonstration, National Highway Institute, implementation, and highway planning and research programs, have been used in addition to state funds and personnel.

CONCLUSION

Technology transfer is not new: What is new is the emphasis to accelerate the process, to shorten the time it takes for usable research to become accepted practice. What is new is the emphasis to create the multiplier effect from federal to state, from state to state, and from state to city to county. These are the key objectives. I believe the programs and activities discussed provide evidence that, during the last few years, great strides have been made by the highway community in bridging the gap between research and practice. The foundation is now set for further improvements, and to do this requires that the momentum of our current efforts be continued.

REFERENCE

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Local Government Technology Transfer

James E. Shamblin, Center for Local Government Technology, Oklahoma State University, Stillwater

This paper describes the initiation and progress of a university-based technical-assistance program for local governments. Initially funded by the National Science Foundation, the program began with a statewide needs-assessment program that had input from both municipal and county officials via five workshops. Both technical problem areas and barriers to technology were identified and categorized. The program has operated for more than three years, providing technical assistance via quick response to individual requests, technical workshops, and major research and development projects, which use faculty and students. Examples of technology-transfer programs and some assessment of their credibility and impact are presented. Recommendations for newly emerging programs are summarized: (a) an attitude of sharing with other organizations is essential, (b) local credibility is the single most important factor, and (c) work should be on user-selected problems. Inputs for future policies and programs are presented: (a) there is a significant need for a nonagricultural extension service, (b) to implement federal research there must be a final linkage at the local level, (c) definition for federal research must begin at the local level, and (d) federal agencies should give higher priority to implementation.

The Center for Local Government Technology is a public-service program of Oklahoma State University. It provides assistance to city and county governments in the implementation of engineering and management technology in order to improve the productivity of delivery of local services. Oklahoma is a relatively young and rural state. Local government bodies consist of 77 counties and approximately 982 incorporated villages, towns, and cities. Income is generated from agriculture (40 percent) and petroleum and manufacturing (splitting the remaining 60 percent).

The program began with a National Science Foundation (NSF) grant to conduct a statewide assessment of local needs and to develop a program that might best meet these needs. A series of five district meetings was held with county extension directors and other local personnel from the Cooperative Extension Service. The purpose of these meetings was to establish personal liaison between the program leaders (Joe H. Mize, Charlie A. Burns, and myself) and to explain how the center would relate to the established extension program. Next, a series of five workshops was held in these districts to meet with government officials from local municipal and county governments. These workshops established problem areas and technical needs, current resources, and barriers to the use of technology as a problem-solving tool. Technical problem areas were grouped into three major categories, which were divided into subgroupings as indicated below:

1. Equipment management—specifications preparation and selection, maintenance, and replacement decisions;
2. Public works management—planning of road and bridge systems for rural counties, street maintenance, planning and operation of solid waste systems and water and sewer systems, and calculation of the costs of public services; and
3. Manpower management—job descriptions, manpower scheduling, determination of optimal crew size, incentive plans, manpower training and retention, and functional organization.

During these meetings, six major barriers to technology transfer were identified:

1. Unawareness of information,
2. Lack of trained personnel,
3. Inability of experts to be understood,
4. Inadequate finances,
5. Lack of confidence in technical information, and
6. Resistance by operating personnel.

Many potential resource agencies and organizations were identified, but, on closer questioning, almost none provided the final link to the use of problem-solving technology. Most officials from smaller units of government were generally unaware of any potential resources.

CHARACTERISTICS OF LOCAL GOVERNMENTS

As a result of these workshops and three years of operation providing technical assistance, the following summary could be made regarding the nature of local government:

1. Expediency oriented,
2. Autonomy of operation,
3. More services demanded,
4. Tax burden too high,
5. Labor intensive but low pay scales,
6. No tradition of efficiency, and
7. Inadequately trained personnel.

Most elected and appointed officials are not inclined to make long-range plans. Most decisions are highly influenced by the term of office. There is little incentive to make tough decisions that will only bear fruit in the long term.

Most units of local government in Oklahoma are relatively autonomous from state and federal government. They guard this autonomy zealously and resent outside controls or influence.

Constituents of all governments are demanding higher standards of public service. Citizens of small towns expect benefits and services similar to those provided in larger municipalities. All citizens feel recent tax needs are excessive and resist providing new revenue sources.

City and county governments are labor intensive and expend a majority of their funds in the form of wages. Generally, these wages are below those paid for comparable positions in industry. For a myraid of reasons, most units of local government do not have a tradition of seeking to obtain an efficient operation. Few even attempt to establish meaningful measures of productivity. For whatever the reasons, smaller units of government badly lack trained people in both the operating position and lower supervisory levels.

PROGRAM OPERATION

The Center for Local Government Technology has adopted and adapted the basic strategy of the Cooperative Extension Service to the degree that funding limitations would allow. In all cases, the center seeks to emphasize that the ultimate product be problem solving in nature and usable by the appropriate personnel at the local level.

Major problem areas were first identified in the series of workshops held for local officials. A users' steering committee provides a major resource in the identification and evaluation of other major problem areas. In addition, a significant input resource comes from the feedback provided by local government officials on a statewide basis through personal contact, reference from the Cooperative Extension Offices, the Oklahoma Municipal League, state legislators, and "hot line" service offered by the center.

Major problem areas that require significant resources for research and development generally receive separate funding for research to be conducted by individual faculty and students. Center personnel assist in arranging for testing of results in actual municipal or county operations and help disseminate the material to other units of government via workshops, demonstrations, manuals, and fact sheets.

Center personnel generally provide the major portion of short-term (quick-response) technical assistance via personal interaction with individual local officials. This may be the result of a technical request via the hot line or as a follow-through step after a workshop or seminar. The ideal technology-transfer process would make use of individual assistance to increase credibility. This is generally provided in the Cooperative Extension Service, but funding requirements make this impossible for the center to maintain on a truly statewide basis. As a result, the center tries to emphasize quick response, well-prepared and tested program materials, and multigroup assistance via workshops and fact sheet distributions. The professional staff of the center have degrees and experience in engineering and technology, but they often draw on the experience and expertise of faculty in other disciplines. It has been shown that, until the proper person in local government has been identified and informed, little technology transfer will occur. Reports disseminated without backup or local expertise are seldom used.

SUMMARY OF RESULTS

The most important results are not reflected in quantitative terms; however, even in these terms steady progress can be documented. For example, during the initial stages of the program, the center received approximately one request for technical assistance per week. Now the center receives more than that just from out of state. Our most recent survey indicates approximately two or three requests per day, an increase of 10-15 times. Credibility has been greatly improved. For example, we now get requests from user groups to assist in their own programs, such as the annual training programs of the City Managers' Association of Oklahoma or the Oklahoma chapter of the American Public Works Association. A total of 112 officials from Kansas, Arkansas, Colorado, and Texas attended a recent two-day workshop on municipal flooding. The examples below are given as a measure of the impact of the center on municipal and county governments.

One problem identified in the original needs study was the need to replace faulty bridges on the county road system. Funding had not been available and replacement costs were excessive. L. A. Maciula developed the concept of a mass-produced, field-assembled standard bridge design. Together with the County Government Educational Services Center of the University of Oklahoma, we presented and explained this concept to the governor's office, the state legislature, the Oklahoma County Commissioners' Association, consulting engineers, the Oklahoma Department of Transportation, and the steel and concrete industries of Oklahoma. The Oklahoma Department of Economic and Community Affairs provided funds for the design of a series of prestressed concrete bridges and the United States Steel Corporation provided the design for longer standard-format steel-based bridges. The state legislature appropriated $250 000 to conduct a series of demonstrations of building new bridges by using these designs and to plan for a larger program next year. The center is responsible for developing and monitoring this demonstration program; the University of Oklahoma center is preparing plans for next year's more general program. A legislative committee appointed to review this problem has recommended a $5 million/year program. It is important to note that this year's appropriation of $250 000 is the first time in more than 30 years that money has been appropriated to county government. So far, three bridges have been constructed and others are in various stages of planning.

The center also brings previously developed technology to the attention of local government via a demonstration workshop. In this case, an instructional workshop is conducted in the morning to present the concepts and the details on the merits of the technology and how it should be used. In the afternoon, the participants attend a working demonstration of this application. An outstanding example of this was the demonstration of the use of Mirafi sheets to control groundwaters under a surfaced road in Stilwell, Oklahoma. Both municipal and county government provided men and equipment to remove the existing section of road, prepare drainage, install the Mirafi sheets, and relay and surface the roads. Municipal and county officials and workers from both Oklahoma and Arkansas attended. This was the first use of this technology in Oklahoma. We would like to think that this program has many similar examples.

The problem, or imagined problem, of overlap with other organizations has been minimal. In essentially every case where a problem has appeared to exist, when contact was made, the problem was either nonexistent or resolved simply. After the first series of workshops on needs evaluation, the center decided that its role would be in the area of engineering and management technology because this area had the greatest void. Another major reason for the minimal problem is the philosophy adopted at the start of this program to not create problems via turf wars. The needs are so great that no organization can fill the demand—so what if two organizations provide similar service? Cooperation has resulted in strengthening both programs. A classic example is the relationships of the center with the Oklahoma Municipal League. The center serves as a major technical resource and backup for the league. In this mode, the league often delivers program material developed by the center. This may give the appearance of overlap, but it is really a significant cooperative effort. In most cases where program overlap is cited, it is due to the lack of awareness of information on the part of the viewer.

Different approaches must be taken to deal with the needs of county versus municipal government. In general, the causes of these differences may be attributed to the following:

1. County commissioners are elected; most city managers are professionals, hired especially for that capability;
2. Municipal services are much broader and thus require a broader base of technology; and
3. County government (with the exception of a few large counties) is influenced by rural or agricultural needs much more than are towns and cities.

Additional problems arise from turnover of personnel. This results from elections, dismissals, and normal job switching. It would normally be a significant, detrimental factor at both the state and local level due to the importance of maintaining program identity, awareness, and credibility. This appears to be typical and must be coped with; therefore, new programs need to be fully aware of this problem.

RECOMMENDATIONS

To summarize what we learned into a requirement for success to share with newly emerging programs, the following items are proposed. An attitude of sharing with other organizations is essential. Turf wars are nonproductive and deadly. Good projects create enough glory for all participating organizations. Share projects, publicity, and success with all organizations that should be appropriately included.

Local credibility is the single most important factor. This means deliver solutions, not reports. Quick response is essential. All material must contain the appropriate level of technology presented in operational terms. Your people must conduct investigations on site, not in the office. Work on the problems identified by your public, not the ones that you are interested in. Be sure your solution works and makes them look good.

A significant need exists for a nonagricultural extension service, in both the public and private sectors. However, it must present usable problem solutions, not just social programs. It must have a federal base of funding, but funding does not necessarily have to be 100 percent federal. The service could be effectively located and operated by a state university. Economics could result if a working relationship could be established with the cooperative extension service.

If the results of federal research are to be used on a broader basis, the dissemination mechanism must have a final implementation linkage at the local level. Simply spreading the work via reports, brochures, computer networks, or the like will not promote use. Federal research that is to be used at the local level must begin with problem definition at the local level and end with a field test of the results at the local level to ensure that the material can and will be used. Federal agencies should give higher priority to the implementation of the results of their research. To do this, a mechanism that links all federal agencies to local users must be developed and used. To prevent excessive duplication via many federal networks, they should give serious consideration to funding local programs to provide this final on-the-spot linkage.

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Local Government Technology Transfer: A Service User's View

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Technical information gathered as a product of research is most valuable when it is usable in day-to-day applications. Useful application of technical information can be achieved early if recognized conduits of information are established and the relationship of researcher and implementor are recognized. The Federal Highway Administration, state departments of transportation, and National Association of County Engineers

have traditionally been the agencies that provide information to transportation agencies, and they should be encouraged to expand on the existing information-distribution system. Technical information can be more valuable to a greater user audience if the following points are recognized and implemented. First, established and recognized systems for the distribution of transportation-related information are essential. State departments of transportation should be encouraged to maintain highly visible secondary road departments to actively carry on technical-information dissemination and technical support to lower governmental units. Second, elected officials should recognize that their transportation officials need to participate in technical conferences and seminars, both as contributors and recipients in the learning process. Elected officials and governmental managers should encourage employee participation in peer group activities for the purposes of information exchange. Third, research projects should be developed that use potential product users as participants and advisers. The Federal Highway Administration and state departments of transportation should expand the use of research data digests and technical briefs to alert and advise cities, counties, and townships of available research information. Fourth, document failures; not all research results in success. Visibility of unsuccessful efforts may suggest different courses of actions for future research. Fifth, technical data can and should be digested to provide a base for public information use. Too often, the transportation engineer fails to recognize the public's need and right to know about what precipitated a final decision. Last, update existing technical data periodically. Rapidly changing transportation events require revisions in guides and standards to ensure that current and future needs are met. Additional methods for alerting potential users about technical information should be developed along with methods to stimulate user application. These systems can be an extension of assignments within the agencies cited in this report.

The most sophisticated experiments in the transportation arena are impractical if they have no impact on the populus. We have come to the realization that the fallout effect of many experiments has been a great boon to individuals far removed from the initial research effort. The final value of any research effort is determined by its application to everyday activities. Recognition of the relationship of the researcher-experimenter to the user of the product (in this case, research and the resulting compilation of technical information) is a must to realize the greatest value from the research. With this need in mind, the Highway Extension and Research Project for Indiana Counties (HERPIC) was formed at Purdue University, as was the Local Road Research Board (LRRB) in the Minnesota Department of Transportation. The need also prompted the formation of the National Association of County Engineers and the evolution of the research committee within that organization.

THE MINNESOTA LRRB

The Minnesota LRRB is a committee of city and county engineers and consulting engineers who have transportation interests and work with the staff of the research department of the Minnesota Department of Transportation, the University of Minnesota, and the Saint Paul Technical Vocational Institute for the development and implementation of research projects and the dissemination of technical information.

A needs and use subcommittee of the LRRB meets semiannually to select projects from suggestions of interested parties and committee participants. Suggested investigative subjects vary greatly in scope and nature. Projects have been conducted in local vegetation use and control, road maintenance methods and materials, new construction procedures, and different applications of old procedures. Once selected, the investigated subject is assigned a number and title that remains catalogued with the Minnesota Department of Transportation for retrieval.

The needs committee sets priorities, establishes funding, participates in site selection for physical experiments, and selects the research team or organization to conduct the work proposed. The head of each research project provides the board with a project report at the semiannual meetings. Interim changes in project status or extended authorities needed by the researchers are usually approved via telephone conferences. During the last few years, the research committee has made it a practice to tour the sites of ongoing and recently completed physical research projects. The assigned project researcher and the local engineer participant meet with the committee at the project site to consult on these projects. These site visits provide participants with better insight into project problems and final results.

When each project is completed, a digest of the information gathered and the results are compiled, and the board reviews the project to determine whether it should be published. In any event, the project retains the gathered information under the original catalogue number and title for future recovery. Completed and published research projects are placed in the data library at the Minnesota Department of Transportation and are available to other agencies through the Transportation Research Information Service Network (TRISNET) program.

Use of data stored in TRISNET and approximately 60 other data-base systems are available to Minnesota agencies through the Minnesota Department of Transportation library computer terminal.

Availability of information and use of the library computer system has been the topic of several panel sessions at the annual Minnesota County Highway Engineers Institute, which is conducted jointly with the University of Minnesota. The four-day institute is attended by county engineers, their assistants, the staff of the State Aid Division of Minnesota Department of Transportation, and Federal Highway Administration (FHWA) regional personnel. Its purpose is to update secondary roads authorities in regulatory and technical areas as well as to provide a format for the open exchange of general information. The LRRB and the National Association of County Engineers Research Committee report to the attendees on various research projects during this meeting.

Major cities and counties that have adequate staffs are able to screen and digest research reports and technical information and apply the data to local needs; however, smaller municipalities and rural counties usually do not have this capability. The Minnesota LRRB project number 645, Implementation of Research Finding, directed by Eugene L. Skok, is one effort to bridge this gap. In 1975, a cooperative agreement between the LRRB and other participants established a contractual arrangement whereby Skok, a professor of Civil Engineering at the University of Minnesota, assumed the task of creating a method of integrating both ongoing and completed research projects into local transportation activities. Skok's familiarity with local engineers, the research projects, and local needs places him in an excellent position to suggest application of project data to local needs. He confers with the responsible engineer user and outlines the proposal and assists in design and application of project data. He remains in contact with the user until the project application is completed. Because the system is new, additional evaluations of on-site use of research material have not yet been compiled. In the future, the information gathered from the user will be added to the project file so that greater project scope will be available to information seekers.

Minnesota's short construction season confines activities into a tight time frame and precludes Skok's close contact with many of the projects during construction periods. There is a need to provide subcommittee assistance and review during the application period. A working subcommittee assigned to each implementation project would improve liaison between the user and the research board.

The LRRB also publishes a monthly digest of transportation research projects and articles that have possible local application. This digest is prepared by Miles S. Kersten, of the Department of Civil Engineering, University of Minnesota. The publication is mailed to all government agencies that participate in the Minnesota State Aid Highway Program and, on request, to consulting engineers and engineering schools. The digest also identifies contacts for obtaining additional information on the published subject matter.

THE NATIONAL ASSOCIATION OF COUNTY ENGINEERS RESEARCH COMMITTEE

The National Association of County Engineers (NACE) Research Committee is a service supplier and user in the technical information and research areas. Committee research is usually conducted in the areas of transportation management. They explore methods for disseminating technical information compiled by others and tailoring this information to needs at a county level.

A permanent subcommittee advises the executive board of the association on the various technical needs of county engineers nationwide. The research committee activities are coordinated through Marian Hankerd and the staff of the National Association of Counties Research Foundation. Selected projects are assigned to committee members who have volunteered to participate in special interest areas. Project information is usually gathered by individual committee members, who work separately and meet as necessary in workshop sessions throughout the life of the project.

Much of the information gathered for county use is a digest that readily lends itself to dissemination in the form of guideline booklets used by operating personnel and, because of this, much of the very technical matter has been deleted except for reference use. There is little need for field personnel to know the exact experimental procedures used to determine finite specifics, such as determining structural steel strength needed for bridge construction or concrete pavement loadings, so long as the user recognizes that the suggested guidelines have suitable foundation. If the need for further information develops, it is imperative that the user have a method of securing that information through a recognizable information conduit.

NACE also uses its membership to provide a one-to-one working arrangement by placing county engineers who have developed expertise in specific areas in direct contact with other engineers who request technical assistance. Through the NACE newsletter, carried in the weekly county newspaper, approximately 1500 county engineers are alerted to the availability of new or updated technical material, technical meeting schedules, changes in federal regulations, and proposals for the development of transportation-oriented legislation.

With organizational membership, each new county engineer receives a copy of each of the publications developed by the organization as a nucleus for the county public works library. These publications are not intended to identify standards but to provide general guidelines in areas where standards have not been established. Each publication identifies the committee members responsible for developing the information, so engineers who seek additional assistance can readily contact them.

A $2\frac{1}{2}$-day management and research meeting is held annually to coordinate the activities of the various county engineer working groups and committees, to review ongoing research, and to select new project areas. Attendance at the spring research meeting averages 175 engineers, public works directors, and road superintendents, who actively participate in workshop sessions on various selected subjects. Recently, the areas of high interest for these workshops are changes in federal regulations, right-of-way acquisition, personnel management, and government tort liabilities.

The county engineers association has made a practice of evaluating various public works activities with the goal of transmitting the recognized best practices to those who need assistance. It is apparent that, with more than 3000 counties in the United States, only half of these receive the information through mailings. Approximately 23 states and Canada have strong county engineer organizations. In most states, a definite relationship links the secondary roads engineers (city, county, and township representatives) to the state highway departments and state transportation departments. This does not always mean there is a cooperative exchange of information. Cursory review indicates that Minnesota is one of the few states that has a program of information continuance between the state and other transportation authorities. Although most federally funded programs require cooperative planning between agencies, the responsible coordinating agency is usually unable to provide the lesser governmental units with suitable technical information to allow for adequate participation and representation. It is necessary that local units of government be appraised of the ongoing research and the volumes of technical help available. The general need for this information flow reaches beyond the ability of a general planning agency or coordinating unit as the unit to dispense technical information. The information must be channeled through technically aligned groups; thus, public works and transportation data generated by TRB and other aligned agencies should be properly directed through FHWA to the states and regional governments, then to counties and cities.

TRANSFER OF INFORMATION BETWEEN FEDERAL AND STATE GOVERNMENTS

Recognition of the information transfer gap at the federal-state interface has resulted in establishment of the FHWA Implementation Division. FHWA's recent program of reviewing ongoing research with other transportation agencies through regional meetings is a step in advancing the practical use of research projects.

Establishment of an annual meeting sequence and expansion of the attendance to include secondary roads personnel, who will eventually use the information and implement research, can provide better insight for the theorists to the needs of the user. It will also alert potential users to newly available data and ongoing research. User input to experimental research and data development at an initiating stage will allow for earlier use of developing research. It will reduce the possibility of continuing research and gathering information that lacks practical application.

A program to expand audiences at technical meetings to include participants at various educational and interest levels could create a whole new atmosphere. At times, the same faces, minds, and intellects seem to meet to rehash the same problems year after year. The introduction of researchers, academic leaders, and the implementors to each other at technical meetings provides the best available opportunities for informational exchange.

It is difficult for government and private business managers to understand why several persons who have various responsibilities should attend the same technical meeting. The answer is that each has something different to learn and a different need to learn. It is important for them to understand the other's needs. Although it is important for a researcher to have a practical interest in the research, it is far more fruitful to have research that is of interest to others. It is more fruitful to have general interest research and a method of disseminating the results. Technically oriented employees should be encouraged to look beyond the boundaries of their assigned duties and to participate in and comment on projects that might be considered beyond their scope, and, above all, they should be encouraged to critique research and technical data when asked to apply the results to their operations.

SUMMARY

The world's transportation industry has advanced as rapidly as most professional endeavors during the last century. It has also created more than its share of problems. As transportation professionals, we are responsible for delivering all the products and benefits the other professional fields develop; and, therefore, we should make it a point to be understood. In order for others to understand us, we should understand ourselves. An assured method of distribution of transportation-related information is essential. State departments of transportation should be encouraged to maintain highly visible secondary roads departments that actively carry on technical information dissemination and technical support to lower governmental units. Elected officials should recognize the importance of appointed transportation officials' participation in technical conferences and seminars, both as contributors and recipients of the learning process, and should encourage memberships in peer groups for the purposes of information exchange. Leaders in the academic and research areas should invite the user to join in the development of research and resulting data. Digesting research data and technical information and preparing a format for application should be expanded through state departments of transportation and made available to local transportation authorities. Document failures; visibility of failures will allow others to avoid the pitfalls. State agencies and county organizations have an obligation to keep the public informed, and no better method exists than to have participants in public endeavors understand the need and scope of a program. Technical information can and should be digested and edited to serve the public information need. Additional methods of alerting potential users of research data, technical information, and data recovery systems need to be developed. The vast storehouses of transportation information will continue to go untapped if we do not provide the user with a method of reaching that information. There is a great need to provide periodic updating of developed information. A prime example is the public's refusal to accept current highway design standards and the methods used for determining transportation facility capabilities and needs. As transportation experts we may be technically correct, but the public frequently questions the foundation for our recommendations, and more often than not, this creates an impasse situation.

Peer groups, in cooperation with FHWA and state departments of transportation, are capable and should be used to develop and disseminate transportation-related data. The state departments of transportation that do not have designated secondary roads divisions should be encouraged to develop these departments. NACE should continue to seek expansion of its participatory membership. Current cooperative research programs that involve FHWA and TRB should be continued to attain this end.

Measuring the Effectiveness of a Research Program

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The purpose of this paper is to present various traditional techniques used to measure the effectiveness of a research program and to identify steps that can be used to improve its effectiveness. There is considerable variation in how the effectiveness of a research program is rated depending on the subjective point of view of the individual rater. Some of the methods used include benefit/cost, reduced accidents, lives saved, and improved aesthetics with benefits generally exceeding costs by a ratio of nine to one. Some steps identified for improving the effectiveness include (a) agreement on the need for the research and a definition of the problem by all concerned, (b) identification of the wants of administration, (c) literature search for a possible existing solution that can be used, (d) redefinition of the problem, (e) prioritization of research needs, (f) conduct of research in a proper manner with guidance from an advisory panel, (g) involvement of potential users, (h) writing the report in the language of the user, and (i) implementation in a timely manner. The importance of a well-organized program that embodies good management concepts is stressed as the means of providing maximum benefits of research through proper and timely implementation.

Over the last several years, much concern has been expressed on how to get research findings into practice. A significant time lag existed between when the research was completed and when the results were put into use. This was both unnecessary and undesirable. Communication was identified as the major problem contributing to this time lag. Steps were taken by the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and others to close this gap, and these have resulted in more complete and timely research implementation. Large sums of money have been expended annually for research and development activities, which total approximately $350 million by the U.S. Department of Transportation (DOT) of which $50 million was spent by FHWA. The research program has been diversified to cover a wide spectrum of areas.

Efforts have been made to show the benefits of research through the use of benefit/cost relationships. These have been almost always determined by the researcher, and they have been used to determine the effectiveness of a research program and, therefore, to justify its continuation. Other items used as a measure of effectiveness have been reduced accidents, saved lives, improved aesthetics, and improved environment. Reports that discuss research programs all point out that benefits far exceed costs; benefit/cost ratios are approximately 9 to 1.

How do you measure the effectiveness of your research program? How you measure the effectiveness of your program is strongly dependent on your point of view. Our point of view influences our opinions. In addition, our measurement of the effectiveness of a program is dependent on our expectations. If we get more than we expected, then we are pleased; if we get less, then we are displeased. An administrator may view the effectiveness of a research program entirely differently from the researcher. One level of management may be satisfied and another one may not. In general, the measurements of research effectiveness are subjective and are therefore subject to individual feelings, which result in different values from different management levels or disciplines.

Is there an objective method that can be used by everyone that would always produce consistent results? Is it possible to get all individuals who are concerned to look from the same overall broad point of view? Some methods that have been used as a means of measuring effectiveness are the following:

1. The number of reports published in trade magazines,
2. The number of awards,
3. The number of studies implemented,
4. The percentage of studies implemented,
5. The overall benefit/cost ratio,
6. The number of implementation packages,
7. The improvements in operations resulting from research,
8. The percentage of the research results adopted by others through technology transfer, and
9. The size of the research budget.

Some of these would not be very meaningful to a highway or transportation administrator who is primarily concerned with getting problems solved. Research is of little or no value to practitioners unless the results can be applied. This is the only way a return can be obtained for the investment. The major reasons for undertaking research studies are to find solutions to problems or to satisfy some need. At times, research may be undertaken to meet the requirements of some directive or legislative act.

I believe there are things that can be done to produce a common broad point of view and improve effectiveness. This can best be accomplished by following certain steps and obtaining agreement at each step by all those concerned. The first point of agreement must be on the definition of the problem or the need for doing a particular type of research to everyone's satisfaction and understanding. This is the first critical communication relating to a potential research study. If an understanding cannot be reached at this point, then there will be greater disagreement when the study is completed. As a researcher, I must know what the administrator needs so that I can provide a proper solution. It is essential that agreement be reached between all concerned on a well-defined problem or need.

As numerous problems are identified and defined, it soon becomes obvious that some of these problems may already be completely or partially solved. These solutions, if available, must be sought out and matched with the problems. Competent personnel must evaluate the potential solutions to the problem to make certain they are properly matched. There is certainly no need to solve the same problem every few years. Once the available information is evaluated and fit in, the problem statement should be adjusted to everyone's satisfaction so that only the new information required to effect a solution will be sought. It is sometimes very difficult to tell if a solution exists in the literature due to the titles, abstracts, and the manner in which the reports are written. The Federally Coordinated Program (FCP) is very useful in determining what needs to be done in a wide range of topics. The Highway Research Information System (HRIS) is also very valuable. The decisions reached through evaluating available information and redefining needs cannot be taken lightly because they are very critical. They can play a large part in the cost of conducting the research and the time required to obtain the useful results.

Once the problems have been defined, evaluated, and redefined as needed, there are generally more to be solved than finances and staff can support. This necessitates placing the problems in some order of importance or priority by using a procedure or technique to get the most from available funds. Some of the factors that are important and should be considered in establishing priorities are the following:

1. The urgency in finding a solution to the problem: How critical is the problem?
2. The probability of being able to find a solution: What are the chances of success?
3. The potential benefits that can be achieved if a solution is found: What is the expected benefit/cost relationship?

The major reason for priority setting is to minimize the risk involved in conducting the research and maximize the benefits that may come from it.

The next critical step after the research program is established is to obtain the proper solutions through research. One of the keys to successful research is the use of advisory panels to provide guidance during the conduct of the research. The advisory panel must be fully aware of and agree on the statement of the problem and the study objectives. The first step is the preparation of the research proposal by the potential researcher based on the problem statement and study objectives. The proposal should be based on good experimental design procedures and should be realistic in its approach to finding a solution. A good experimental design goes a long way in minimizing unnecessary expenditures and maximizing benefits. The completed proposal should be reviewed by the advisory panel and modified as needed by the researcher prior to beginning the study. Everyone should be in agreement with what the researcher intends in the proposal to avoid confusion and misunderstandings later. A well-thought-out proposal only partially guarantees success, since the qualifications of the researcher conducting the study are also very important. The researcher must have (a) the necessary technical and administrative skills to conduct the study properly and (b) a good understanding of the problem and its relationship to the study objectives. This will help to avoid misdirection. A researcher can be easily misled by some new-found knowledge and concentrate efforts on details unimportant to achieving the objective. Involvement of potential users on the advisory panel helps ensure early and successful implementation when results become available. Implementation is first considered in the problem statement and begins with the proposal. Checkpoints are potentially useful tools for study progress reviews. In this way, a proper course can be maintained. Useful results should be disseminated early to help expedite the implementation process. The various reports, interim and final, should be well organized and prepared and should be written in the language of the user.

Even after the final report is prepared, successful implementation is not guaranteed. Effort is still required. If all of the previous steps were properly followed, then the implementation step will be relatively simple. Implementation is not complete until the results are put into use through the media of practice. It is of no value to develop new improved materials or techniques if there are no specifications, standards, or procedures to ensure application. Research results must be implemented to ensure maximum benefits. This does not mean that all results should be applied, since some results are negative. Some steps that have been identified and described for research implementation are the following:

1. Identification—this is accomplished in the problem-identification phase or through the review of results developed by others that have a potential benefit.
2. Planning—this is started during the problem-identification phase and continued through proposal preparation to the completion of the research.
3. Packaging—this is accomplished with the report and any additional documents for the media of practice to ensure proper implementation.
4. Promoting—this is started with the research proposal and is primarily done by the researcher and the advisory panel. It is completed when the results are adopted.
5. Adoption—this is accomplished when the results are accepted in the media of practice to solve the problem or to satisfy the need originally identified.
6. Evaluation—this phase includes the final identification and documentation of the measurable benefits.

If all steps are properly followed with the involvement of key personnel, then the measurements of effectiveness by different management levels and by different disciplines would be comparable.

There are three basic types of implementation efforts. The one I have been discussing is where research has been conducted in response to a problem and the results are implemented to solve the problem. The second type is where the problem exists, and information for the solution is obtained from outside sources, then adopted for use by the organization. This involves to some degree a transfer of technology. The third type is where a problem has not been specifically identified but information has been identified that, if and when implemented, the system would be improved or costs could be reduced. Implementation packages prepared by one agency are effective tools in bringing usable results to the attention of other agencies in a form that they can easily adapt. Implementing results developed by others can significantly reduce time and money by the using agency.

If the research program is set up in a manner similar to the one discussed, with key personnel involved throughout all phases, then there should be agreement on the effectiveness of the program. Everyone is looking for essentially the same thing and their expectations are the same. It can be frustrating and embarrassing to find solutions to nonexistent problems or to find the wrong solution through misdirection of the research effort. A properly planned, organized, and conducted research program does not always ensure 100 percent successful results, but it certainly does improve the chances of producing worthwhile results, whether positive or negative. The manner in which research is planned and conducted and the results implemented plays a significant role in determining how effective the research program will be.

How we measure the effectiveness of a research program depends to a great extent on our point of view and on our expectations. We hope to be able to resolve any differences and develop a system that can be applicable to any level of management or discipline in measuring the effectiveness of a research program.

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Examination of Techniques to Enhance the Utilization of Research Results

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During the past several years, transportation problems have become increasingly more severe in spite of a growing effort to expand the state of knowledge in transportation. A considerable amount of quality research is conducted, but there appears to be a breakdown in the process of transferring these research results into practice. Much effort is devoted to the conduct of research; however, in many cases, the process of implementation and research utilization are ignored. This paper examines the research process and emphasizes major problem areas that hamper implementation within this process. Several barriers to the implementation of research results are identified and discussed. Attention then turns to the results of a study of the characteristics of transportation research conducted at universities and funded by the Urban Mass Transportation Administration program of University Research and Training. On the basis of the results of this study and a review of the literature, eight basic principles relevant to the process of research implementation are presented in conjunction with mechanisms for increasing the level of implementation. These principles demonstrate a need for greater communication between researcher and user and a need for the users of research to become involved in all phases of the research process.

Many researchers have recognized that, despite the large volume of applied research, too often the results of this research are not implemented. During the past several years, transportation problems have become increasingly more severe in spite of a growing effort to expand the state of knowledge in transportation. A considerable amount of quality research is conducted, but there appears to be a breakdown in the process of transferring research results into practice. Much effort is devoted to the conduct of research; however, in many cases, the process of implementation and research utilization are ignored. This paper examines the process of research utilization and the barriers that hamper this process. In addition, an attempt is made to establish some general principles that can be used to overcome some of these barriers. The problem of research implementation addressed in this paper will be couched in terms of urban transportation research conducted at universities and targeted for state or local user agencies. Nevertheless, we believe that the basic principles and processes discussed are applicable to almost any research context.

It is important at the outset to distinguish between basic and applied research, for this distinction will serve to narrow our focus. Colman (1, p. 2) and Haworth (2, p. 116) believe that the distinction is based on the intent of the researcher. A researcher engaged in basic research is primarily interested in the advancement of knowledge (i.e., contributing to the theory of a discipline or area of inquiry). In applied research, the researcher has practical, specific objectives. That is, the expectation is that the research will have some practical utility for others. Further, the applied researcher often expects that the results of the research will influence the decisions of people who are in a position to effect policy change.

THE RESEARCH PROCESS

Research almost invariably involves the same sequence of steps:

1. Recognition of the problem,
2. Problem definition,
3. Theory building and explanation,
4. Information gathering,
5. Information analysis and interpretation,
6. Development of conclusions,
7. Formation of recommendations, and
8. Implementation and action.

The potential usefulness of a research project can be affected by the way in which each of these steps is undertaken. If there is a substantial deviation in how things are viewed by the researcher and how they are viewed by the user, the likelihood of eventual implementation is decreased. Thus, if the researcher fails to recognize or properly define a problem in a way that is meaningful to the user, the probability of implementation of the research is limited. In a similar fashion, if the researcher and user disagree on theory, information, analysis, or conclusions, the probability of implementation is also lessened. This general process leads to the first axiom of research utilization.

Axiom 1: Probability of Research Utilization Is Inversely Proportional to Distance Between Researchers and Users of the Research

In other words, research utilization is enhanced through the involvement of the potential users of the research in the entire research process. They should be involved in problem identification, problem definition, theory building, information gathering, information analysis, conclusions, recommendations, and implementation.

In general, the deviation between researcher and user viewpoints is not the result of a deliberate attempt by either to subvert the process; but rather, it is usually a result of other factors. One of these factors is the communication process between researcher and user. If the communication between researcher and user is infrequent and formal, more difficulty in implementation would be expected than if it occurred frequently and on an informal basis. When communications are more frequent and informal, user and researcher are more likely to identify points of deviation as they occur and to correct them before they become irreversible. In addition, there is an ease of information transfer and a greater degree of understanding of the other person's needs and intents.

Axiom 2: Probability of Research Utilization Is Inversely Proportional to Degree of Formality Between Researcher and User

A corollary of this is that the probability of utilization is directly proportional to the level of effective communication between researcher and user. Another factor that may cause a deviation between the researcher and user is differences in the organizational structure of the agencies involved. This is particularly true if the research takes place at a university and the user is a mission-oriented agency, such as a transportation department of a governmental unit. These two types of organizations have very different patterns of operation and structure. In most universities the individual researcher is nearly autonomous in terms of how and what research is conducted. He or she works in an environment where the development of new ideas is the norm and where people are at ease in challenging existing policies and procedures. Also, he or she is accustomed to making decisions on the path the research should take, with little review from others. The university researcher's main objective is to publish.

In a mission-oriented user agency, the organizational pattern is quite different. The individual user of research often is faced with extensive review of his or her efforts and must deal with a large set of constraints and conflicting views. Usually, procedures and policies have been institutionalized, and it is difficult to change them without considerable effort. Thus, the process of implementation of a research result in an agency can be highly complex and, unless the ideas are well sold, it may be easier to do nothing.

Axiom 3: Probability of Research Utilization Increases with the Degree of Understanding that Researcher and User Have of Each Other's Problems and Motivations

It is important that both the researcher and the user understand the environment in which the other works. If this is the case, both can recognize some of the barriers to research implementation that may develop.

BARRIERS TO RESEARCH UTILIZATION

Once a research project has been successfully completed in that the stated objectives have been met and the research has some potential utility, it is useful to look at the process of utilization of the research. The utilization process includes three basic phases: dissemination, acceptance, and implementation. Dissemination can occur by both formal and informal means. Formal means almost always involve written material, such as project reports, technical papers, or publications, and are likely to have the widest distribution. Informal dissemination can occur in a variety of ways but generally involves person-to-person contact between someone familiar with the research (who may have learned about it through a formal means) and a potential user of the research.

Given that the research has been successfully disseminated, two final steps must take place for implementation to occur. The potential user must accept the ideas presented in the research and must be able to put them into practice. There are many reasons why this may not occur; an effort is made to identify them in the following paragraphs.

The problem has been poorly defined. This often occurs when a problem is defined with limited input from user agencies. Research agency personnel tend to define problems along disciplinary lines and have a goal of advancing levels of knowledge; user agency personnel tend to define problems along policy lines and have a goal of making decisions. Obviously, extensive interaction between the research and user agencies is desirable to define mutually acceptable problem statements.

The research is not valid internally. That is, the research may have been conducted improperly, contain mistakes, or the conclusions drawn improperly. Internal validity is extremely difficult to assess for anyone other than the researcher unless the research is thoroughly and completely documented.

The research may be valid, but the results are not disseminated. Lack of dissemination may be the result of financial, institutional, or other constraints. Also, the research may be disseminated but not in sources readily available or frequently used by its potential users. This problem can occur when research results are published in publications that are not consulted by research users.

The research disseminated may not be relevant to the problems of the potential user. That is, the research does not address or properly articulate a problem as perceived by the potential user. Often this occurs because the potential user agency does not play an active role in the definition of the research problem.

The research is relevant, but the solutions proposed are not feasible for the agency because of legal, institutional, financial, political, or other constraints. The research does not have relevance in a decision context. If the researcher does not distinguish between variables that are subject to manipulation by the user agency and situational variables that are not subject to manipulation, the research results will be of little or no use in a policy context.

The potential to use the research exists, but the user is unwilling to develop this potential for other reasons, such as concerns for its implications to other programs, internal politics, or general resistance to change. The research results are not presented at the proper time. Research results that may have some relevance to a decision may be presented at a point after that decision or irrevocable commitments have been made. In such a case, the research may prove to be counterproductive in that it may cause excessive delay or major conflicts on a particular project.

The research is presented in an unacceptable manner. The research may be used to counter policies of an agency or to generate conflict over agency projects. In this case an adversary situation often develops, with negative results. A positive situation might have otherwise occurred if the research had been presented in a different manner.

The results of the research are not assimilated by the potential user. If research results are to be implemented, they must be assimilated by those who are in a position to facilitate implementation. When results are not presented in the language of the user, it is unlikely that assimilation will occur. Valid, implementable research results are not always presented to persons in policymaking positions. Often the researcher, whether from a university or an agency, simply does not have access to the policymaking process.

The research may not be implemented because of constraints associated with the organizational structures of research agencies and implementation (user) agencies.

Obviously, there are many more possible reasons for the nonimplementation of research results. In an effort to investigate the validity of some of these barriers, a project was initiated and supported by the Urban Mass Transportation Administration (UMTA) through the University Research and Training (URT) program at the University of Wisconsin, Milwaukee.

CHARACTERISTICS OF UNIVERSITY TRANSPORTATION RESEARCH ACTIVITIES

Initially, the intent of the research was to determine, through a sample of UMTA-URT institutions, the extent to which the respective programs had

1. Produced theoretical versus applied research in urban transportation,
2. Disseminated research findings to transportation agencies and other UMTA-URT program institutions,
3. Caused a perceived impact on community transportation problems through the implementation of research results by local agencies, and
4. Involved local community agency personnel in the training or research components of the program.

Major emphasis was to be devoted to the second and third objectives; the remaining two were to be given only cursory examination. As the project progressed, the focus was redirected more toward implementation. Preliminary discussions with URT project directors and a review of some relevant literature revealed that the problem of implementation was poorly understood in the context of transportation research conducted by university researchers.

Implementation has received little formal attention in university-oriented transportation research. The study conducted by the Program of Policy Studies in Science and Technology of the George Washington University (3) recognized the relatively low use of research results as a shortcoming of the then UMTA grant program. Recent work by other transportation researchers has examined implementation in a variety of contexts. The results of these efforts are useful, but they tend to oversimplify the implementation process (4, 5).

Operations researchers and management scientists have recently begun to take a serious look at problems of implementation of operations research models in organizations (1, 6-9). Results are considered implemented if they influence the decision processes of managers. Unfortunately, most of the work has concentrated on implementation within organizations that have also conducted the research; only a few have addressed the problem of implementation when one organization conducts research targeted for a user organization (7, pp. 53-73). Some of the results of these studies are relevant to research in transportation.

Study Design

The literature review and preliminary discussions with selected URT program directors provided the background for this study. Because of financial and other constraints, a sample of URT programs was drawn for study. In addition, interviews were conducted by telephone with project directors. Each interview required approximately 75 min. A random sample of nine institutions was initially drawn, but two of these were eliminated from the study because of difficulties in contacting the project directors.

The interviews were structured around a questionnaire, which was divided into four parts. The first part contained questions designed to elicit information on the research focus of the respective URT program. Included in this category were questions related to research orientation (theoretical or applied), subject area orientation, individual project size, number of projects, and faculty involvement in the program.

Questions in the second part dealt with research dissemination activities. Here an attempt was made to determine the extent of dissemination of research results, whether the program had an explicit policy for dissemination, the channels used, and the degree to which URT programs disseminated research results to other URT programs.

The third part consisted of questions relative to research implementation. Because of inherent difficulties in obtaining information on implementation, most of the questions in this section attempted to elicit the opinions and attitudes of the respective project directors. In this section, an effort was made to secure information on frequency of implementation of URT research by local transportation agencies, the nature of the impact of URT research efforts on community-related transportation problems broadly conceived, the partial or holistic implementation of research by local agencies, problems and constraints associated with implementation, and how to improve the URT program's effectiveness in providing useful research to transportation agencies.

The fourth set of questions is closely related to the previous set and addresses the degree of transportation agency involvement with the URT programs, whether this involvement was direct or indirect, and opinions regarding the nature of communication between URT program personnel and agency personnel. The interviews were conducted during the summer and fall of 1974. An effort was made to elicit meaningful, accurate responses from the project directors. However, some of the information requested was dependent on the respondent's memory of past events.

Part 1: Research Focus

The response to the question, "What is your estimate of the relative proportions of basic and applied research conducted by the UMTA-URT program at your institution?" was as follows:

Program Number	Basic (%)	Applied (%)
1	10	90
2	20	80
3	10	90
4	30	70
5	0	100
6	25	75
7	80	20
$\bar{X}$	25	75

Several respondents expressed difficulty in distinguishing between basic and applied research. In these situations, basic research was defined as research primarily aimed at advancing knowledge in a discipline or area of inquiry and applied research was defined as research that has practical, specific objectives and practical utility.

The next question was, "What is the subject orientation of this basic and applied research?" Orientation of basic research included demand modeling, experimental psychological models, mode-choice modeling, dial-a-bus, transit rider preferences, and freight handling. Applied research was oriented toward transportation education, mass transit, transportation planning, modal split, modeling transit systems, transit planning, mode choice, and transit system performance. It is interesting to note that research on mode choice was mentioned in both categories. This suggests that a fundamental difference between basic and applied research is one of approach and emphasis rather than subject.

The response to the questions, "Within your program, approximately how many research projects have been undertaken within the last year (or last year of full funding)?" How many of these would you classify as large-sized projects? Medium-sized projects (in terms of financial and manpower commitments)?" was as follows:

Program Number	Number of Projects	Project Size: Large	Medium	Small
1	6			6
2	6			6
3	8			8
4	8	1	2	5
5	7	2	1	4
6	5		1	4
7	4			4
$\bar{X}$	6.3			

Therefore, 7 percent of the projects were large, 9 percent were medium, and 84 percent were small in size.

The response to the question, "How many faculty were associated with your URT program during a typical year on a part-time basis? on a full-time basis?" was as follows:

Program Number	Faculty: Part-time	Full-time
1	5	
2	10	2
3	2	
4	4	
5	6	
6	4	
7	8	
$\bar{X}$	5.6	

In all but one case, faculty involvement was interdisciplinary. If this sample is representative of all URT programs, interdisciplinary involvement in the research program was achieved. However, such involvement on a project-by-project basis probably does not occur as frequently. Rather, researchers from different disciplines work on separate projects more often than not. Unfortunately, this contention is unsupported at this time and is a suitable topic for further research.

Part 2: Research Dissemination

The response to the question, "With respect to project research reports, do you have any explicit policy regarding the dissemination of these reports?" was as follows:

Program Number	Response
1	Yes
2	No
3	Yes
4	Yes
5	Yes
6	No
7	No

Of the affirmative responses, two programs had a policy of sending all reports to state and local transportation agencies, advisory committee members, and other interested parties, by using a standard mailing list. Selected reports were then prepared for submission to the National Technical Information Service (NTIS) and journals and for presentation at meetings. The remaining two programs had explicit policies for distribution to state and local agencies and advisory committee members but no set policy regarding other forms of dissemination. This does not mean that these programs or those that responded negatively to this question did not engage in dissemination efforts. Rather, they had no explicit plan of action for dissemination.

The response to the question, "Approximately what percentage of your programs' research is distributed through the following means?" is given below:

Information Distribution	Percent
Program cover (e.g., technical or research reports)	92
NTIS	40
Transportation journals	23
Other journals	1
Oral presentation	
Meetings	17
Local seminars	5
State and local conferences	2

Three of the seven project directors interviewed had considerable difficulty in responding to this question. The percentages reported above are averages for the remaining respondents. Since responses were very similar, the average is a representative measure. The four directors who were able to respond generally seemed intimately knowledgeable about the activities within their respective programs.

In response to the question, "Do you send copies of your research reports to other UMTA-URT programs?" four replied frequently and three said infrequently. This question was an attempt to gain some insight into the frequency of dissemination by this channel. The complement to this question is, "Do you receive research reports from other UMTA programs?" The response pattern was identical to that of the previous question. In virtually all cases, copies of reports either sent or received were few in number. Typically, a program director would send report copies to a few selected friends at other programs.

The next question was, "Which specific research project, conducted under your UMTA program, has attracted the most attention outside of your institution?" This was an open-ended question, and an effort was made to elicit the nature of this attention. Given the dissemination efforts made, the intent of the question was to obtain subjective information on feedback from the sources of interest. In most cases, one or more local transportation agencies expressed interest in a particular project. This usually resulted from the distribution of research reports to these agencies. Occasionally, interest was expressed through requests for copies of the report; these requests were based on recognition of research in NTIS, in a transportation journal, or at meetings. In a few cases, projects gained negative attention, especially when the research addressed controversial transportation problems that were sensitive issues in one or more local agencies.

In response to the question, "Have you experienced any particular problems or constraints with the dissemination of your research findings?" four respondents acknowledged the existence of particular problems, two of whom mentioned cost as a major factor. They were of the opinion that insufficient funds were available to effectively disseminate research results. The other two respondents expressed a concern for problems associated with the effective ways to encourage investigators to finish reports on time.

Answers were varied to the question, "Do you have any suggestions on improving the dissemination of research results to other UMTA programs and to potential users?" The only common element was suggestions to increase the amount of money available for report preparation. One respondent thought that UMTA should distribute the reports. Another respondent saw a need to develop a system to identify potential users better; a logical starting point was the development of better communication between UMTA programs. Still another respondent thought there was a need to recognize that the users of the research are not transit operators but other universities. Thus, it is essential to improve the flow of information from university to university. One way to accomplish this would be to have student-oriented meetings on a regional basis where research would be presented and discussed. Transit operators and other local agency personnel could be invited as panel members. In addition, there was a general feeling that UMTA should have been more consistent and frequent in circulating statements about research progress at funded institutions. Finally, a few respondents thought that the best way to achieve effective dissemination was to involve user agencies in the research process.

Part 3: Research Implementation

In response to the question, "Do you feel that implementation by local agencies of research results emanating from UMTA-URT programs occurs... ," one said occasionally, five said infrequently, and one said very infrequently. Respondents were asked to give some justification for their answers. These can be classified into three types:

1. URT programs engage in small projects that are not that applicable and the research does not address the right problems,
2. Lack of involvement by personnel from local agencies results in low implementation rates (without such involvement it is difficult to establish the communication channels necessary for implementation to occur), and
3. There is a general mistrust of university faculty on the part of many local agency staff.

In response to a question about the impact of the research efforts of UMTA-URT programs, all seven replied that they had a positive impact. Justifications for these responses were given, both in terms of the training and the research components of the program. They may be summarized as follows: First, the programs have had a positive impact because of the training of persons for positions in state and local agencies. During a three-year period, one program accounted for the placement of 15 people in such agencies. In the long run, this is probably an effective means for increasing university-agency communication and agency involvement in research. The products of a small research project are likely to have only short-range impact, if any, whereas the education of persons in transportation is a long-range investment that improves with age. Second, at the local level, the research conducted by some programs generated interest where none would have otherwise existed. Generally, the research may not be implemented, but the exercise of the research effort was worthwhile for the educational process, both within the university and the community.

In response to the question, "To the best of your knowledge, have any of the results of research projects, conducted under your UMTA program been implemented, in whole or in part, by state or local transportation agencies?" three respondents answered affirmatively. Since implementation is sometimes a nebulous term, only relatively clear-cut examples were considered. It is quite possible that implemenation took place without the knowledge of the project director. In all cases, implementation occurred in state and local transportation agencies (both public and private) and planning commissions. Another common element of these implementations concerned the involvement of agency personnel. In all cases, agencies were intimately involved in virtually all phases of the research process. In two of the three cases, the projects involved students who were also employees of local agencies.

Responses to the question, "In your opinion, what are some of the typical problems or constraints associated with the implementation of research results?" were divided into the following categories:

Category	Number
Research is not disseminated	1
Research is not relevant in a policy context	1
Research does not address specific problems	3
Research is not of an applied nature	2
Implementation of research results is not feasible for agencies because of legal, institutional, or financial constraints	4
Research is useful, but the user is unwilling to use it because of its implications to other programs, internal politics, or general resistance to change	4
State and local agencies rely on other agencies for research results	5
Other	2

The numbers recorded above represent the frequency with which each item was selected as a problem or constraint; multiple responses were permitted. Problems in the other category included unwillingness of agency personnel to use the program as a resource for the planning and implementation of research results and difficulties in timing the availability of research results with agency needs.

In response to the question, "What steps do you feel might be taken to improve the UMTA-URT program's effectiveness in providing useful research results to local transportation agencies?" the following suggestions were made by the respondents.

We should attempt to increase the involvement of agencies in research by coordinating university research interests with agency needs. This is not an easy task, but it can be accomplished by first developing a rapport with agency personnel. Effective communication channels must be developed and research needs identified.

The program needs focus. Virtually all resources should be used to upgrade the quality of transit management through education. Research results will not be used unless management is improved.

If universities want to do applied research, much of it will have to be narrow in focus. Researchers will also have to get to know agency personnel well. Transportation agency-university relations are not good. The differences between research and development cause problems since the university is concerned primarily with research and agencies with development. Articulation of the differences between these two activities may be helpful.

Local agencies should be encouraged to use the university as a resource. Considerable expertise exists in many universities, but it is not effectively used by agencies primarily because no mechanism exists for effective communication through cooperative research efforts.

Part 4: Transportation Agency Involvement

All responses to the question, "Are there any state or local transportation agency personnel involved in either the research or training aspects of your program?" were affirmative, and an attempt was made to determine the nature of this involvement. The nature of involvement was divided into two categories, direct and indirect. The results that follow reflect the frequency of response for all seven respondents, not the number of personnel involved.

Involvement	Number
Students take courses	4
Personnel work on research project	
Personnel teach in the program	2
Personnel make presentations in seminars or conferences	3
Members of advisory committee	6
Members of steering committee	5
Consultant	-
Informal information	5

It should be noted that the selection of these categories was the result of initial discussions with project directors not included in the sample. At the time, the items in these two categories were considered to be representative of the majority of agency involvement.

Since the listing of responses to this question does not reflect individual response patterns, it is important to point out that agency personnel were involved directly in only four programs. In addition, if one compares this result with the results of a previous question concerning the actual implementation of the results of a research project, an interesting observation can be made. That is, those programs that reported concrete examples of implemented research results all had agency personnel directly involved in some aspect of their program, typically as part-time students. This observation has important implications for those interested in developing effective mechanisms for implementation. Of related importance is the finding that all agency involvement in the seven programs was the result of efforts initiated by the respective program personnel.

Conclusions

The majority of the research conducted by UMTA-URT programs in this survey was of an applied nature. Yet few examples of implemented research results were identified. Is this due to inherent difficulties with the process of implementation or is it due to the possibility that implementation cannot be examined formally? Is implementation articulated as an explicit process of putting the results of a research project into practice or is the process one that is informal, fragmented, and diverse? Obviously many degrees of variation are associated with implementation, and more research is required to examine some of these.

As mentioned previously, dissemination is an important component of implementation, but its role in the research process must be reexamined. It used to be common (and probably still is) to think that implementation began when a research project ended. The same holds for dissemination. In certain situations, these two activities can play an important role at the end of the research process. However, in terms of the vast majority of urban transportation research, dissemination and implementation must be viewed as important components at all stages of the research process. The results of this research partially support this contention.

MECHANISMS FOR INCREASING THE LEVEL OF RESEARCH IMPLEMENTATION

As a result of this research and a review of relevant literature, certain basic principles, which are appropriate for the researcher interested in implementation, can be stated. These principles are applicable to applied research and serve as guides for anyone interested in increasing the level of research implementation. Different situations require that different subsets of these principles be adhered to in order for implementation to occur.

The first principle states that research results must be timely [i.e., the results (holostic or partial) must be available to the user at the time of the decision]. This decision, whatever its nature, may be viewed as part of a decision chain that incorporates many interlinked decisions. That is, each decision in the sequence is dependent on the previous decision. The conduct of research and the flow of research results should ideally parallel this decision-chain process so that the accumulation of research results coincides with, and has important implications for, each stage of the decision process.

The second principle is concerned with the relevance of the research in a policy context. It may be stated thus: If, in the conduct of applied research, the researcher fails to distinguish between variables that are subject to manipulation by the user and variables that are not, the implementation of results is unlikely. Since implementation often involves a policy change, it is important for the researcher to emphasize policy variables and possible ways in which they may be used to institute changes (1).

The third principle is as follows: To increase the probability of implementation, the researcher must include the user in the definition of the problem stage and other relevant stages of the research process. Too often researchers approach a potential user with completed projects—ones in which the users have had no input. Under these conditions, the user has difficulty relating the results to particular situations since the problem definition may not be acceptable.

The fourth principle is closely related to the third and states that, for implementation to occur, it is imperative that the researcher translate results from the language of academic inquiry into a language that is understandable to the targeted user agency. Although seemingly self-evident, violation of this principle is common, and transportation agency personnel often complain about the technical language used in research reports. As mentioned previously, implementation is dependent on communication, but communication is hampered if the user cannot understand the results or the implications of the results (1).

The fifth principle may be stated as follows: The investigator must conduct research in a responsible, objective fashion. This means that, in the conduct of the research and in the presentation of results, the researcher should attempt to subdue personal values and interests and not engage in advocacy. However, advocacy may be appropriate in making recommendations (which are, of course, based on the research results) to user agencies (1). However, if at all possible, the researcher should avoid situations where advocacy leads to severe conflict with the user agency.

The sixth principle is as follows: Recognize that implementation frequently requires some change in the methods of operations of the implementing agency. Bureaucratic organizations are highly resistant to change, but the researcher may be able to foster and encourage implementation if good rapport has been developed with key agency personnel.

The seventh principle states, The common element underlying successful implementation is communication. That is, effective information transfer is crucial to the implementation process. It is important to recognize and deal with problems that hamper this transfer. "Success is impossible without enlightened users and sponsors who have achieved ownership of the study. Only then will a climate of confidence favor successful implementation" (7, p. 291).

The eighth principle suggests that, in situations where a research project has promising potential for implementation, it is important at the outset of the project to plan implementation along with the research.

These principles are not necessarily all-inclusive, but they have been stated in general terms so that the reader may deduce more specific principles from this basic set. Adherence to these principles and recognition of the various barriers to implementation mentioned previously implies that the researcher be conscious of the process of implementation and the role it plays in the conduct of research. Thus the conduct and implementation of research should be viewed together.

The researcher who is sincerely interested in the implementation of research must engage in more than the mere conduct of research as traditionally defined. He or she must take an active role in the implementation process and be willing and able to develop working relationships with the appropriate agencies. He or she must comprehend the nature of these agencies, their organizational structures, their interests, and the constraints under which agency personnel must operate. He or she must realize that implementation will not always occur despite best efforts. Even though the research may be of a high quality, the elements of the particular situation will be against implementation. Each researcher must know the organizational environment in which he or she operates, change those elements that are susceptible to change, and accept those that are not. In addition, the researcher should conduct responsible research that is timely, and the results should be presented in a constructive manner.

In general, there is a need to examine more thoroughly the process of research implementation in different contexts. This could be accomplished by several intensive case studies of situations in which the management and conduct of research lead to implementation. These case studies could then be used to further articulate the conditions under which the implementation of research results is most probable. A better understanding of the barriers to research implementation awaits further inquiry.

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University Management of a Transportation Department's Research Program

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The Transportation Center of the University of Tennessee has entered into an agreement with the Tennessee Department of Transportation to manage a university research program. Six state universities and the University of Tennessee cooperate in the program. The Transportation Center manages the program as part of its research management functions and is the contracting agency. The commissioner of the Tennessee Department of Transportation and a vice president of the university have the final authority in all contractual matters. An office is maintained within the Tennessee Department of Transportation headquarters. The program encompasses research in all modes of transportation and involves many disciplines. An executive committee formulates policy, approves the work program, and approves the awarding of research to the various institutions. A technical advisory council is responsible for all technical aspects of the program. Monitoring teams work closely with the researchers and are responsible for implementation of research findings. The technical aspects of the program include the formulation of research needs through the development of problem statements, which are ranked in the order of need. The highest-ranked problem statements are developed into requests for proposals and forwarded to the cooperating universities, which respond in accordance with their capabilities. The proposals are evaluated, and an institution is selected to conduct the research. Agreements of understanding then are prepared and executed.

The Tennessee Department of Transportation and the University of Tennessee have developed a research management program that is unique in many respects. The program is organized to function basically along the same lines as the National Cooperative Highway Research Program (NCHRP). From its creation in December 1970, the program has grown from a purely highway-oriented research program to one that encompasses all modes of transportation. The first program director was employed in March 1972 as an assistant director of the university's Transportation Center. This research management program initiated the university's Transportation Center and the Tennessee Department of Transportation's full-fledged University Research Program. Under this program, all state universities in Tennessee are able to participate, and the Tennessee Department of Transportation draws on a vast reservoir of knowledge available through these institutions.

In 1951, the Tennessee general assembly passed an enabling act that authorized the department of highways to enter into an agreement with the University of Tennessee for research in highway design, construction, and maintenance. The act was implemented that same year, when the university and the department of highways established the Tennessee Highway Research Program on the Knoxville campus. The program functioned with an advisory council, consisting of an equal number of highway and university representatives, that had the responsibility of supervising and directing program activities. A director was appointed by the university, in concert with the advisory council's review, to provide technical direction of the program. Research activities of the program during its 19 years of operation were directed primarily to meeting the department's research needs in the field of highway materials; limited work was performed in the areas of economic benefit and land-use studies.

The department's research needs changed over the years. Its emphasis is now on providing a balanced transportation system for the state. Because of these changing needs and emphasis, the department conducted a careful review of the activities of the Tennessee Highway Research Program, with the intent of recommending changes where appropriate and desirable in order to redirect the resources of this partnership in such a way as to provide a broader base of research support for total transportation throughout the state. This preliminary review included a study of the feasibility of involving all of the state's higher educational institutions in research to the extent of faculty interest and qualifications. In 1970, at the invitation of the department of highways, university staff met with department staff to discuss restructuring the joint program. It was immediately apparent that, in order to meet the total transportation challenge in Tennessee for all modes of transportation, a broader-based organization should be considered.

A joint task group was formed to explore and report on alternatives for structuring and implementing a research program that would assist the department most effectively in meeting its obligations and would provide the basis for initiating a comprehensive transportation research and advisory service program that served all modes of transportation. The task group gave attention to such matters as the need to find useful solutions to problems of immediate concern, the desire to bring researchers in closer contact with persons within the department who are associated with the problems, the need to provide for the implementation of practical and feasible results, the desire to foster development of a program that ultimately can play an important role in the total transportation activity of the state, and the desire to involve the state's several higher educational institutions.

As a result of the task group's report, a formal agreement between the department of highways and the university was signed in December 1970, to establish the University Research Program, which was the beginning of the Transportation Center and its research management program. The agreement ensures a cooperative research program for the department in which all state institutions of higher education, having the necessary facilities and expertise to conduct the needed research, can participate. The current level of funding to support the research to be conducted under this program was authorized by an act of the state legislature, which became effective on July 1, 1970. The administration of the Transportation Center is located within the university structure so as to provide a relationship with the university as well as with the academic units on the main campus at Knoxville and the other campuses. Figure 1 shows that the Transportation Center is not located within a particular college but in the universitywide Office of Graduate Studies and Research.

On July 1, 1972, the Tennessee Department of Highways became the Tennessee Department of Transportation, broadening its scope of responsibility to include all modes of transportation. In September 1972, the Transportation Center became fully functional, with a main office on the Knoxville campus and a satellite office in Nashville, designated as the Tennessee Department of Transportation Division, to manage the University Research Program.

Research projects originate through a technical advisory council. This council is analogous to the committees of the American Association of State Highway and Transportation Officials (AASHTO). An executive committee, which functions similarly to the executive committee of TRB, has the responsibility of reviewing and approving all actions of the technical advisory council. The Transportation Center acts as the managing

Figure 1. Location of the Transportation Center within the university.

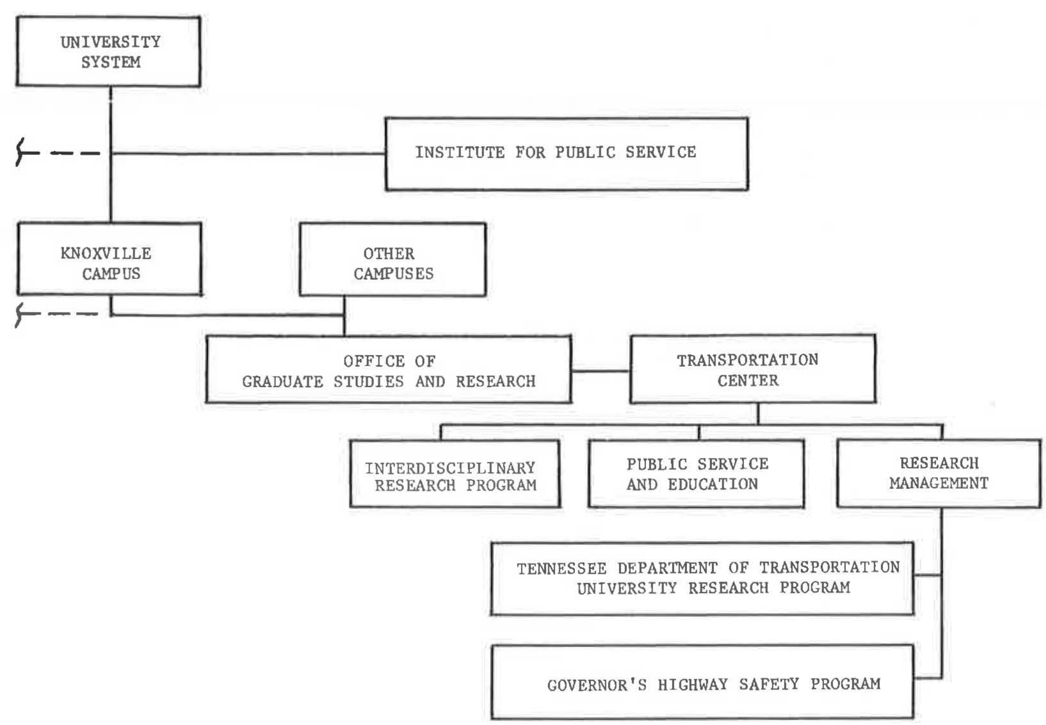


Figure 2. Research management unit of the Transportation Center.

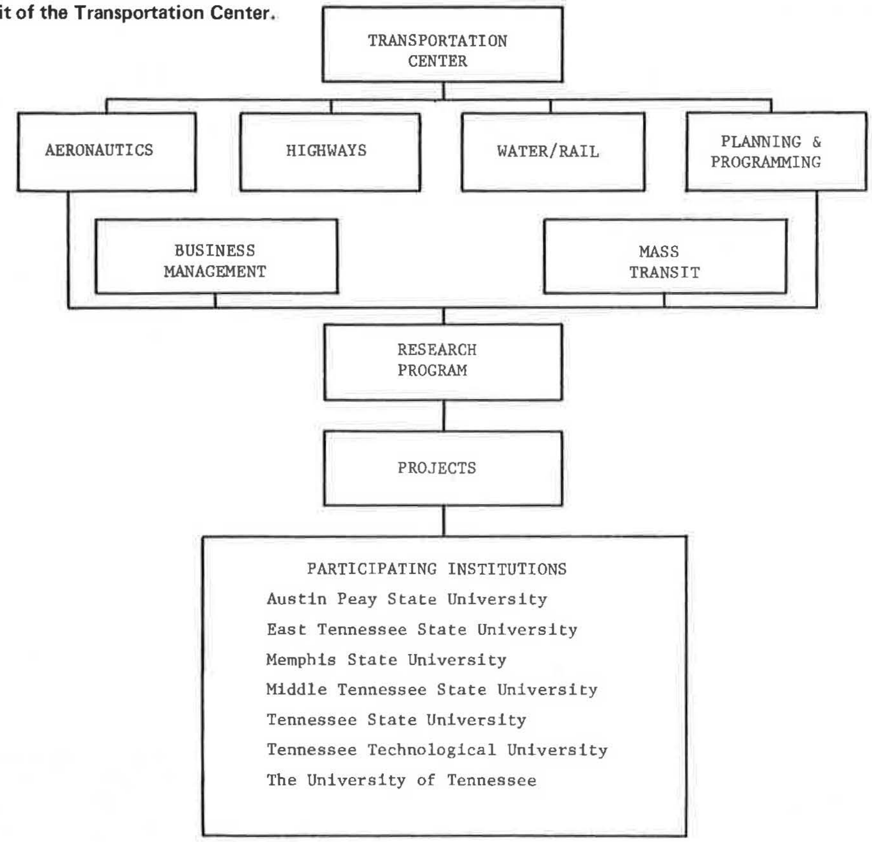
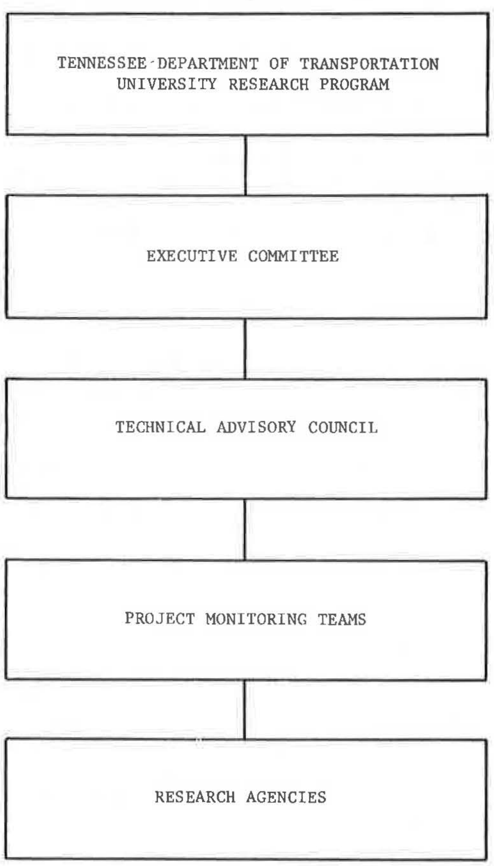


Figure 3. Structure of management units.



agency for the conduct of authorized research and is officially the contracting authority. The management of the research by the Transportation Center is quite similar in almost every respect to the management of research by NCHRP.

ADVISORY ORGANIZATIONS AND FUNCTIONS

Research, training, and educational activities undertaken in a particular functional area (such as highways, mass transit, or waterways) are carried out with the review, advice, and approval of the technical advisory council. The technical advisory council is composed of technical persons from the various operational divisions within the functional areas. In addition, participating institutions, including the Federal Highway Administration (FHWA), are represented by institutional liaison members, who can participate in the deliberations of the technical advisory council and advise on (among other things) the available manpower to perform studies. Subelements of the technical advisory council (monitoring teams) participate in monitoring the research and aid in implementing research results. An overall policy group (executive committee) sets policies, establishes funding levels, and exercises final approval on programs. The membership of the policy group is composed of the head of each functional area being served. The desire of the Tennessee Department of Transportation is to organize the needed research activities. The general structure of the functional areas as related to the Transportation Center is shown in Figure 2. Figure 3 shows the relationship to the Tennessee Department of Transportation. In order to accomplish the program objectives in an orderly manner, this arm of the Transportation Center is housed physically within the Tennessee Department of Trans-

Figure 4. Functions of the technical advisory council.

TECHNICAL ADVISORY COUNCIL

TENNESSEE DEPARTMENT OF TRANSPORTATION
DIVISION HEADS/ASSISTANT DIVISION HEADS

Construciton
Materials
Structures
Planning
Soils and Geology
Right of Way
Programming
Maintenance
Design
Traffic
Aeronautics
Personnel
Transit
Water

INSTITUTIONAL REPRESENTATIVES

Austin Peay State University
East Tennessee State University
Memphis State University
Middle Tennessee State University
Tennessee State University
Tennessee Technological University
The University of Tennessee

- o Define Research Problem Areas
- o Establish Research Needs
- o Recommend Priorities
- o Develop Projects
- o Review Results
- o Use Results

portation's headquarter offices in Nashville.

Executive Committee

The executive committee and its chairperson are appointed by the commissioner of the Tennessee Department of Transportation. This policy group has overall responsibility for the program. The committee is made up of the directors of the various bureaus within the department and was established to review, approve, and authorize all actions of the technical advisory council on the research projects funded by the department through the center. The director of the Transportation Center, who is an ex officio member of the executive committee, acts as secretariat to the committee and provides the staff services necessary for the committee to carry out its duties and responsibilities effectively. However, the program director, who is an assistant director of the Transportation Center, is responsible for the day-to-day operations of the program and works closely with the executive committee and the technical advisory council in all matters. The executive committee reviews the progress of the program and recommends to the commissioner the annual appropriation for the operation of the program. The executive committee is responsible for the appointment of members to the technical advisory council. The executive committee also

1. Establishes policy relating to the overall program,
2. Reviews and approves annual obligations,
3. Reviews and acts on recommendations of the technical advisory council, and
4. Counsels the director of the Transportation Center on matters related to its administration.

Technical Advisory Council

The technical advisory council was formed to manage the technical aspects of the department's research. The membership of this council is determined by the executive committee and consists of heads or assistant heads of certain operating divisions from the various bureaus within the department. In addition to these members, institutional liaison representatives are assigned by the various institutions that participate in the program. A representative from FHWA is also included. Monitoring teams are formed as needed to monitor particular research projects and to assist in implementing the results. The program director from the Transportation Center serves as the secretariat to the council. Figure 4 shows the structure of the technical advisory panel. The technical advisory council

1. Meets as often as needed (at least quarterly) to review transportation-oriented activities;
2. Defines problem areas, establishes research needs, and recommends priorities;
3. Establishes projects and studies;
4. Provides counsel and advice regarding technical conduct of projects; and
5. Assists in the dissemination, application, and evaluation of the results of studies and projects.

Specific activities of the council include the following:

1. Identification of the research problem areas;
2. Preparation of definitive statement of objectives for projects within the problem areas (project statements constitute requests for proposals);
3. Review of research proposals and recommendations of research agencies;
4. Designation and organization of teams to monitor project activities; and
5. Specific recommendations for implementation of research findings.

Institutional Liaison Members

Six state universities and the University of Tennessee participate. All of the participating institutions have a representative (institutional liaison member) on the technical advisory council. These institutions may submit proposals on proposed projects for which they have capabilities to conduct the indicated research. These institutions also may submit problem statements to the technical advisory council on any area of research they deem appropriate. The problem statements are then considered by the technical advisory council in the same light as problem statements generated within the department. Any unsolicited proposals submitted by the institutions are treated as problem statements. Although not a participating agency, FHWA also may be represented by an institutional liaison member. The institutional liaison members

1. Meet with the technical advisory council to review and comment on existing research activities, to discuss proposed research, to explore new research areas, and to advise on methods and procedures for carrying out research;
2. Maintain, for use in the program, a current inventory of researchers and institutional specialists, their areas of interest, and their experience in the field of transportation research; and
3. Provide the point of contact between the Transportation Center (for the department) and the participating institution.

Although the liaison members have no voting responsibility, they may (and are encouraged to) enter into discussions of any issues generated within the technical advisory council and provide any relevant information. In general, they act as an advisory panel to the technical advisory council. They advise on such things as types of research currently under way, capabilities of their institutions in various fields, how general research is conducted, facilities necessary to conduct research in any given area, and the practicality of any problem tendered.

Monitoring Teams

During the conduct of a particular research project, it is desirable to identify the individuals within the Tennessee Department of Transportation who have the greatest need for implementing the results. These persons, along with the assistant director of the Transportation Center (program director), form a monitoring team that visits with the researcher, discusses the work, and maintains a close liaison with the researcher in an effort to use findings as quickly as they become available. Members of the monitoring team are appointed by the chairperson of the technical advisory council and the technical advisory panel member whose unit has the greatest interest in the research. This team may vary in size from a minimum of three (i.e., the department's division representative, the program director, and the researcher) to whatever is needed to aid effectively in the monitoring of the research. The monitoring team

1. Meets at least quarterly with the researcher,
2. Reviews the research progress,
3. Examines the research findings for possibilities for implementation,
4. Determines if the research is on schedule,
5. Determines if the research is proceeding on the proper course or direction,
6. Performs audits as necessary, and
7. Reports findings, results, and recommendations to the technical advisory council.

The program director has the responsibility for scheduling meetings of the monitoring team with the researcher and for providing for presentations of the research results and findings to the various functioning groups. In addition to reviewing the research as it progresses, the monitoring team is responsible for providing information regarding possibilities for implementation in the field and for reviewing and recommending the acceptance or rejection of interim and final reports.

Program Director

The general responsibilities and functions of the Transportation Center's assistant director (program director) assigned to this program are as follows:

1. To serve as secretariat to the technical advisory council working in concert with the council chairperson in carrying out the programs;
2. To provide for the conduct of specific and general research, special studies, workshops, seminars, and training relating to the needs of the Tennessee Department of Transportation;
3. To establish a working relationship and effective communication with other members of the council as related to fulfilling the research, training, and educational needs of the department;
4. To provide for the monitoring of all program research in accordance with the wishes of the council;
5. To provide the necessary coordination and liaison with related programs and other activities, including those within the participating institutions as well as within organizations throughout the country;
6. To provide for systematic review, evaluation, and application of research results;
7. To maintain a continuing awareness and inventory of current and completed research relating to the department's needs;
8. To cooperate in the maintenance and operation of the department's technical library as a measure of providing the needed program materials; and
9. To assist in the review and dissemination of findings and results from the research completed by other agencies, institutions, and organizations.

The program director prepares and distributes requests for proposals. The director is available to provide assistance to the various cooperating institutions in the preparation of problem statements and proposals as well as to assist in other areas of research effort. The director also is responsible for the preparation and execution of any contracts that originate as a result of the activities of the technical advisory council and for obtaining the approval of the executive committee. It is the program director's responsibility to see that monitoring teams are established, to see that the research is progressing as stated in the contracts and proposals, and to see that reports and other informational sources are generated as necessary.

The program director acts through the institutional liaison members in the preparation and development of the contracts, quarterly progress reports, interim reports, final reports, and closing of the projects. The director serves as a contact between the institutional liaison members, various members of the technical advisory council, and other personnel of the Tennessee Department of Transportation. The program director assists the institutional liaison members in gathering information from the various divisions within the department needed in the preparation of problem statements and in the conduct of research projects and other efforts. The program director also acts as a contact for research project directors and potential researchers.

The program director monitors the financial status of the projects and is responsible for assisting in any necessary audits and in the proper documentation and support of project costs.

The technical staff for this program consists of the director and a secretary. (Basically, the program functions by committee.) Additional help is available through the center's main office in Knoxville and through the committees working with the program director. The Tennessee Department of Transportation provides office space, certain office supplies, phone, reproduction facilities, and mailing services for the program director and staff.

OPERATIONAL MECHANICS

The program director is responsible for the generation of problem statements and, at various times (usually annually), initiates requests for problem statements from various organizations. These requests go to all division heads within the department and to responsible regional and field personnel. Requests also are sent to the institutional liaison members of the participating universities and to anyone within the state's educational institutions who has an interest in or knowledge of research needs pertinent to transportation. They also are sent to other governmental agencies, such as metropolitan planning commissions, transportation authorities, city engineers, county highway engineers, city traffic engineers, and certain civic organizations (e.g., Tennesseans for Better Transportation, the Tennessee Roadbuilders Association, and the Highway Users Federation).

When the problem statements are received, they are reviewed by the program director and are coded as to specific areas of interest (e.g., highway safety, public or mass transportation, or water transportation). Then they are forwarded to the technical advisory council members who are working in the area addressed by the problem statement. The program director queries TRB's Highway Research Information Service (HRIS) to determine what research has been conducted or is under way relative to those problems chosen for research in the program. The program director later visits each of the technical advisory council members to review the problem statements forwarded to that particular member. Jointly, the technical advisory panel member and the program director revise the problem statement to meet the specific needs of the department in the area addressed. The problem statements may be expanded to include other areas, or areas in which no additional research is needed may be eliminated. After the problem statements have been reviewed in this fashion, they are presented to the technical advisory council in a formal session, along with a list of the titles of those eliminated through the first process. In the formal meeting, with the assistance of the institutional liaison members, the problem statements may be revised further. If necessary, they are ranked in order of need or assigned a priority rating. The council determines how many of the highest-rated problems should be recommended to the executive committee for funding in the program. The program director transmits the recommendation to the executive committee for review, acceptance, rejection, or revision.

Proposals

On acceptance of the problem statements and authorization for the funding of the projects, the program director meets with the chairperson of the technical advisory council and the technical advisory council member or members responsible for the work in the area addressed by the problem statements. This team prepares the project statement, which sets forth in detail the problem, the proposed research, and the goals and objectives of the research project. When the project statement has been prepared in an acceptable form, it is forwarded as a request for proposals to the participating educational institutions. The institutional liaison members for the participating institutions disseminate the request for proposals to interested members of the institution's staff. Included in the project statement (request for proposals) is a deadline date for submission of the proposal, information pertaining to the preparation of proposals, and estimated cost of the project.

Researchers use different procedures for the preparation of proposals, but, in general, they are prepared in accordance with a set of guidelines provided by the program director. The proposals normally include a proposed research plan, the proposed staffing, an itemized budget, available facilities, what the researcher hopes to accomplish, how the results or findings may be applied, and a suggested implementation plan.

Proposals are submitted to the program director; copies are then forwarded along with a rating sheet to each of the voting members of the technical advisory council, and a formal meeting date of the council is scheduled. Prior to this meeting, the technical advisory panel chairperson appoints an evaluation committee of technical advisory panel members who work in fields related to the proposed research. This committee reviews the research proposals and visits the researchers for a conference, during which various aspects of the proposal are discussed. The committee examines the proposals for relevance and approach, considers the expertise, capabilities, and past performance of the researcher, and determines whether the institution can provide the support and has (or can obtain) the facilities and equipment needed to conduct the research. This committee reports its findings and recommendations to the full technical advisory panel at the formal meeting. At the formal meeting, a session is provided for discussion of the merits of the proposals, rating sheets are completed and tabulated, and the results are posted. The institutional liaison members and program director may participate in the discussions, but they may not vote.

The technical advisory council uses this process to determine which institution will be recommended to the executive committee to conduct the proposed research. The program director submits the proposals and the recommendations of the technical advisory council to the executive committee, which reviews the proposals, ratings, and recommendations of the council and makes the final decision about the disposition of the project and awarding of the contract. The technical advisory council usually recommends a first and second choice, and its recommendations usually are accepted. However, the decision is based on the amount of research being conducted by the institution recommended, the quality of past performance, and the general distribution of the research effort throughout the various cooperating institutions. When the executive committee awards the project, the program director prepares the contract.

Contracts

Contracts are constructed along a standard form, which is altered and structured to fit each research project. Occasionally, the researcher may be requested to submit revisions or supplements to the proposal that, along with addendums, are incorporated into the contract and become a part of it, as does the project statement. Draft copies of the contract are forwarded for review to the institution approved to conduct the research, to the legal staff of the University of Tennessee, and to the legal staff of the Tennessee Department of Transportation. Any changes requested by any of these agencies and agreed on by the others are incorporated in the contract. The program director is responsible for reconciling differences. Contracts are approved by the Tennessee Department of Transportation and are executed between the University of Tennessee and the university chosen to conduct the research agency. When the contracts are executed fully, the researcher is authorized to proceed. At this stage, the monitoring team assumes responsibility for the project.

In the conduct of any research through this program, it is the policy not only to avoid discrimination in the research projects but also to avoid discrimination in any endeavor or deliberation of any of the participants. In this regard, all participants endeavor to comply fully with all state and federal laws pertaining to discrimination and with any executive orders of the governor pertaining to this subject.

Project Funding

There are basically three sources of funding. The state legislature in 1970 authorized an annual appropriation to the University of Tennessee for the funding of research projects in this program. In addition to these funds, 1.5 percent of the total federal appropriation for highway construction to the state (called highway planning and research funds) is set aside within the department. Occasionally, the various bureaus will have funds in their budgets for specific research projects.

It is the responsibility of the executive committee to determine from which one of these sources the projects will be funded. It is the responsibility of the program director to recommend to the executive committee the best source of funding. Since all the bureau directors are members of the executive committee, there is a general awareness of funds available through the various bureaus that may be available. Occasionally, a research project not given a high priority by the technical advisory council but considered essential by a bureau director will be funded from that bureau's budget. With the approval of the commissioner of transportation, this may be done without the concurrence of the executive committee. Occasionally, but rarely, a project may arise that other state departments may support. In such instances, the program director, with the help and assistance of the executive committee, may approach that department and arrange for joint funding and the development of a cooperative effort. In most instances, a participating university is willing to share cost for the project. Usually cost sharing takes the form of a reduction in overhead costs.

Implementation

This program is directed more toward the solution of problems of great concern rather than toward the pursuit of pure research in areas hitherto unexplored, although both categories are within the realm of the program and are considered when appropriate. In this respect, implementation of the research findings and results is of paramount consideration. With the aid of FHWA and other transportation research organizations, a set of implementation guidelines was developed. In the development of these guidelines, the need was recognized to consider implementation from the time the problem was conceived until such time after the completion of the project that the possibility of implementation could be rejected or the findings could be implemented as deemed adequate or appropriate.

The guidelines address the subject of implementation, beginning with the development of the problem statement, through the preparation of the request for proposals, the development of the proposals, the selection of the institution to conduct the research, the monitoring-team activities, the preparation of interim and final reports, and a period for evaluation after the completion of the project.

In order to have a successful program of implementing research findings and results, it is necessary for those at all administrative levels within the department to be concerned, to take an interest, and to be willing to accept innovative changes. It is sometimes difficult to realize the value that may result from the findings until they are actually tried. But the main reason for such a rigid implementation program is to prevent good research effort from becoming lost and forgotten and to encourage proper and careful utilization of resources.

SUMMARY

The restructuring of the Tennessee Highway Research Program led to the establishment of the Transportation Center within the Office of Graduate Studies and Research at the University of Tennessee. Although the university has an agreement with the Tennessee Department of Transportation to serve its research needs, the Transportation Center functions as a coordinating and (where appropriate) management unit within the university system. This includes providing public service in conjunction with research to fulfill needs in transportation. The nature of the Transportation Center's organizational structure permits it to serve local, state, and federal agencies and private industry in a variety of ways.

This Tennessee Department of Transportation University Research Program has been functional since 1970 and is continually developing research needs and contracting for specific research projects. (An identical program for managing research under the governor's Highway Safety Program has been functional since July 1976.) The program director for the University Research Program is housed in the department's headquarters in Nashville. This represents a unique approach to managing the department's research and is unlike similar organizations, where a university works with a department in assisting with its research program. This approach is believed to be a vital element in developing a program that not only meets the department's needs but also materially aids in the implementation of research results.

Organizational Aspects of a State Transportation Research Unit

Frederick W. Thorstenson, Minnesota Department of Transportation, St. Paul

The integration of highway departments into transportation agencies requires, among other things, a shift in research and development emphasis. The question is raised as to how research and development should be organized and managed to ensure attention to the full spectrum of transportation problems. The approach of one such agency is explained. A survey was made of 29 representative departments; 26 responded to 10 basic questions. Answers, in a collective sense, resulted in conclusions that provide guidance for structuring, operating, and maintaining a strong research and development capability in a state transportation agency. Finally, the reason for a prospective research and development partnership between the Minnesota Department of Transportation and the University of Minnesota is described.

The title of this paper implies that the Minnesota Department of Transportation is struggling with an appropriate organizational concept for its research and development activities. The department made the transition from a highway department more than two years ago. Along with the many changes wrought was a research potential considerably altered from what was essentially a physical research orientation applied to highway materials to the prospect of dealing with a broad spectrum of transportation research and development problems. The transition has not been accomplished coincident with the creation of the department of transportation; it is still going on and will continue a slow evolution into an organizational entity with a full transportation research and development capability. The bureaucratic process of augmenting the research budget and realigning personnel to provide a more versatile capability is another matter to be dealt with, at a time of tight money and personnel complement restrictions. Thus, in organizational format, at least, research and development at the department is still much as it was under the highway department organization.

A great deal of thought and effort is being devoted to creating a more responsive research organization. As a first step, it was decided in late 1977, one year after the creation of the department of transportation, to conduct a survey of research and development organizations and programs in other states. A questionnaire was subsequently sent to 29 states, chosen largely on the basis of known research accomplishments and, in most instances, converted from a highway department to a department of transportation. Each state was asked to respond to 10 questions and to provide details for affirmative answers.

QUESTIONNAIRE

Replies to the questions were received from 26 of the 29 states solicited. Answers varied considerably. Since the questions largely elicited subjective responses, the information provided cannot be readily tabulated. Therefore, the collective sense of the replies was expressed in summary statements.

Question 1

Where does research and development fit within your organizational structure and how is it organized? The pattern of responses shows that coordination of research programs in the majority of cases is centered in the planning and programming function, largely associated with the management of the Highway Planning and Research (HPR) Program funding of the Federal Highway Administration. The exceptions are departments that have strong materials and research offices. In some instances managerial responsibility is split. Where the planning activity controls, the research program is generally parceled out to operating offices, universities, and consultants. Exceptions to this pattern are the California Department of Transportation and the Virginia Highway and Transportation Research Council, the former being an example of internal organizational coordination for a diverse research program and the latter an example of a specially created arm of the parent organization, which operates in conjunction with a university and uses its faculty resources.

Question 2

How broad is your research and development program in terms of serving both hard and soft research needs? Hard research still predominates in most departments; however, there is a decided trend toward soft research, particularly in the areas of safety, economics, environment, and planning. The consensus is that both types need equal emphasis. Management responsibility is usually divided in most organizations—hard research is largely materials-oriented and conducted internally, and soft research is more normally planning-centered and often conducted externally.

Question 3

Is all of your research managed through a central coordinating office, or is part of it conducted by operating offices directly associated with the subject matter and contingent on the availability of time and personnel? The bulk of the states polled provided centralized administrative control of the research program, although in some states, responsibility is split between physical research and research devoted to planning, safety, or special studies. Most states have a research staff, largely with a capability in physical research. States that parcel out research work to operating offices are in the minority.

Question 4

Is all or part of your research program administered through a special council, board, or committee? More than 80 percent of the states that responded incorporate a research board, committee, or council to develop, approve, and monitor the research program. Some of the states that responded negatively once had research committees that had become inactive.

Question 5

Exclusive of your contribution to the support of TRB and the National Cooperative Highway Research Program (NCHRP), approximately what amount of federal and state funds do you devote annually to research and development activities, and what percentage is this of your annual budget? The annual expenditures for research and development ranged from a low of $115 000 to a high of $9 million. Most responding states fell within the $0.5- 2 million range. In terms of annual budget, the range was from 0.10 to 0.77 percent; most of the respondents were within the range of 0.2 to 0.5 percent.

Question 6

Do you maintain a relatively stable research and development staff complement and rely on outside contracts to control fluctuations in the work load? If so, what part of your research and development budget is so managed? All but one state maintained a stable research and development staff, although 5 out of 26 reported that their staff was administrative only. Only four states indicated that contract research was used to control fluctuations in the work load, yet 19 of 26 supplemented their programs with contract research. Where the research staff served largely in an administrative capacity, all research was by outside contract, mostly through university agreements.

Question 7

Do you have a formal relationship established with a university or college system for the conduct of research? Eight out of 26 respondents (roughly 30 percent) indicated some formal relationships with one or more universities. These varied from intermittent agreements to conduct research projects to one instance where the university performed all of a department's research. In another instance, the department and university had created a joint, sustaining research facility.

Question 8

Have you provided organizationally for the systematic implementation of research findings resulting from your own investigation as well as findings from other sources? Of the states polled, 50 percent had no systematic implementation procedure. Most relied on informal technology transfer through the distribution of research reports and other communications. Among the states that had implementation procedures, none were alike. In most instances, responsibility for implementation was assigned to the research engineer, an implementation unit, or an internal committee.

Question 9

Have you established, other than through HPR pooled-funds projects, any formal arrangements or agreements with neighboring states for the conduct of research of common interest? None of the 26 respondents had established any formal arrangement. Eight states cited instances of having shared at one time in non-HPR pooled-funds projects; one was Minnesota's studded tire study, which was shared by eight other states.

Question 10

In your opinion, based on relative potential benefits, should a state transportation department strive for a strong research and development capability or should its role be largely supplemental to national programs? The states replying favor a strong state research and development capability 22 to 4, on the basis of focusing research on local problems and responsiveness to local needs. Those who did not fully agree with that concept expressed the need to adapt national research findings to local conditions.

CONCLUSIONS

What guidance do the survey results provide for structuring an idealized research and development organization within a state transportation department? Some broad conclusions emerge.

A strong research and development capability within state transportation and highway departments is seen as essential to resolving local problems. The research program should be subject to the control of a carefully selected advisory committee, board, or council so that projects are approved on the basis of need, priority, available funding, and diversification. The direction of the research and development program should be vested in a single organizational unit, inclusive of all internal and external research and development duties and relationships, to achieve administrative and managerial efficiency and effectiveness.

State transportation organizations should maintain a staff of competent research personnel to cope with ongoing problems, but they should rely on external talent (universities and consultants) for the more diverse and specialized areas of competence.

A wide disparity seems to exist among states in the level of budgeting for research and development activities, and it would appear prudent to set a goal expressed as a percentage of a department's operating budget. [Although the comparison may not be valid, in private industry an average research and development expenditure for 600 companies amounted to 1.9 percent of sales in 1977 (1).] More states should provide organizationally for research implementation so that research results can be systematically applied and evaluated.

The lack of cooperative research projects among states that have similar geographic and climatological characteristics would suggest a need to consider jointly sponsored projects as a means of resolving regional problems.

CURRENT EMPHASIS OF THE MINNESOTA DEPARTMENT OF TRANSPORTATION

The survey results, plus other circumstances, are influencing the direction of the Minnesota Department of Transportation in its organization of research and development activities. Much of the emphasis and inspiration is being borrowed from the Virginia Highway and Transportation Research Council, which is affiliated with the University of Virginia. This partnership has endured for almost 30 years. Such an affiliation is particularly appealing to the Minnesota Department of Transportation at this time because of plans for a new civil and mineral engineering building on the University of Minnesota campus in Minneapolis and an invitation from university authorities to suggest how the new facility might better serve transportation needs.

Research capability in most state transportation organizations is limited by funding and personnel. Funding is an ever-present problem; however, the building and maintainence of an able research staff is a much greater problem. Engineering personnel generally filter through a research unit on the road to promotional opportunity. It is difficult to hold talented people unless the research unit itself provides that opportunity or unless there is in the department a recognition of a dual-ladder concept as a basis for rewarding exceptional research talent. Still another problem is the greater need today for versatility in the staff to deal with the broad spectrum of both hard and soft research. Affiliation with a university can lessen the severity of these impacts and give the research program an expanded capability in terms of talent and scope.

The Virginia Highway and Transportation Research Council is an operating arm of the Virginia Department of Highways and Transportation, and its director is the research engineer for the department. Thus, under this concept, the department retains full control of its research program and maintains the necessary lines of communication with the operating offices for research problem input and implementation output.

The partnership between the Minnesota Department of Transportation and the University of Minnesota is emerging along a similar path. Up to this point the president of the university and the commissioner of transportation have expressed their mutual receptiveness to the concept. Joint committees are dealing with financial arrangements and organizational structure. The department of transportation sees this as an opportunity to enhance its research program, and the university views it as a means of expanding its reputation for transportation research.

Obviously, not all states would have the opportunity (or would care) to affiliate their research activities with an educational institution. The degree of success of a research program in a department is often dependent on the receptiveness and encouragement of management and the organizational provisions for implementing research results. When these two provisions are fulfilled, even modest research units can make effective contributions to technical progress. The Minnesota Department of Transportation has a research and development section within its office of construction and engineering development. Another section within the same office develops the department's engineering standards (details, procedures, manuals, and specifications). Thus, implementation of research results within that organizational structure is standard operating procedure, well accepted and supported by management. With this well-rooted and accepted foundation coupled with the prospect of affiliation with the University of Minnesota, there is optimism that the department of transportation will reap the benefits of an expanded and diverse research and development program.

REFERENCE

1. R&D Spending Patterns for 600 Companies. Business Week, July 3, 1978, p. 58.

Role of Management Support for Research

Harold C. King, Virginia Department of Highways and Transportation, Richmond

Managers of transportation agencies should recognize that research and progress are inseparable, as reflected in the achievements of research programs in such fields as design, materials, construction techniques, safety, and the environment. On its record alone, research is entitled to full partnership as an integral part of the transportation organization, to adequate physical facilities, and to sufficient manpower and funding. It is well to avoid budgeting all research funds for specific projects. Some funds should be left flexible to accommodate unforeseen, short-term projects and to encourage the research staff to initiate studies for which it perceives a need. Management needs to foster a progressive, organizationwide acceptance of the desirable changes made possible by research activities. Management should ensure that appropriate research results are put to use. Moreover, it has responsibility for evaluating the research effort. One test is to be found in the extent to which research results are used. A simple listing of results that have been implemented, together with a listing of research costs, is helpful. However, reliable evaluation also must take into account the public service benefits derived from research programs, that is, the extent to which public safety, convenience, and mobility is enhanced and the extent to which economies are realized in the expenditure of public tax funds. In sum, management must demonstrate by its attitude that it understands the importance of the research program and assist in setting objectives and in integrating the research function into the total organization.

The achievements of research in such fields as design, materials, construction techniques, safety, the environment, and more are truly monumental. But the unresolved questions that still confront those in the transportation field are equally as monumental. It is necessary to acknowledge, however, that those involved in research are not the only people in the transportation organization who seek management's ear and expect management's support.

Unfortunately, the broad obligations of management severely limit the personal participation of top administrators in any specific areas of the organization. Management must assume the responsibility for seeking favorable legislative relations, because legislative backing is a fundamental requirement for whatever else is to be accomplished. Management must take the leadership in seeing that the organization is administered efficiently, that planning and operational programs are conducted effectively, and that the basic mission of the organization is fulfilled. Management must set the policies and direct the efforts designed to gain the good will of those served by the organization, in this case the public at large. And management must exercise leadership in efforts to recruit, train, and keep a competent work force for all elements of the organization and to attend to a wide range of employee-relations concerns.

There are still more functions, of course, to which the management of a transportation agency must commit its time, energy, and other resources. To fall short in any one of them would endanger the agency's entire program. Because managerial obligations are numerous and often complex, those activities that demonstrate positive contributions to the overall performance of the organization are most likely to earn and to keep management's enthusiastic backing.

Those interested in research cannot expect the undivided attention of management for the research program. What they do expect, and what they deserve, is a management attitude that recognizes the fact that research and progress are inseparable. On its record alone, research is entitled to full partnership as an integral part of the transportation organization. It is entitled to adequate physical facilities and to sufficient manpower and funding to reach the assigned objectives.

Any technically oriented organization that withholds or does not understand the necessity of this degree of support for research is denying itself invaluable help in getting its job done. Change and innovation have become ways of life in transportation. Transportation agencies cannot afford to be regarded as inflexible, self-seeking obstacles to the public good. A progressive research program can avoid that risk by leading the way and assisting agencies in adapting to desirable change. How well it succeeds depends largely on the managerial attitude—a positive attitude can be management's greatest and most enduring expression of support for research. The questions, then, are related to the goals and objectives of research and to the organizational structure through which it is to be conducted.

More than a decade ago, Virginia decided that its objectives in this respect should be directed toward applied research, technology transfer, and troubleshooting. That is, efforts would attempt to improve the policies and practices of the Virginia Department of Highways and Transportation, leaving to such organizations as the National Cooperative Highway Research Program (NCHRP) and the Federal Highway Administration (FHWA) the more fundamental research of national interest.

Three decades ago, the decision was reached that, for Virginia, an in-house staff would best achieve the optimum benefits of an applied research and development program. For that reason, the Virginia Highway and Transportation Research Council was established at Charlottesville, in cooperation with the University of Virginia. It permits the best of both worlds—the benefit of an in-house research team, plus the vast knowledge, experience, and talents of faculty and graduate students at the university.

Much can be gained from an in-house approach to research. For example, an in-house unit can be persistent in encouraging implementation of recommendations that result from research studies, and the translation of recommendations into practice rarely can be accomplished overnight. An in-house staff permits immediate adjustment of schedules if an unforeseen problem occurs, and the scope of a project can be adjusted as the work progresses to meet specified local needs. In addition, a full, formal study can be abandoned readily when the sought-for answer is found. It also is true that research itself is an excellent form of training. There are long-term benefits when this training is experienced by the departmental organization, instead of by someone else. Finally, long-range planning for research may be more readily accomplished when management has its own research unit.

Management's responsibilities do not stop with a positive attitude or with decisions about objectives and organizational structure. Research for the sake of research is worthless. To be useful, there must be implementation and innovation in practice. Management needs to foster a progressive, organizationwide acceptance of the changes made possible by research studies.

Perhaps it is natural, and certainly it is true: If employees see that management takes something seriously, they are more likely to take it seriously too. If employees in a transportation agency observe a respect for, and belief in, innovation on the part of management, that example in all likelihood will permeate the organization.

The Virginia Department of Highways and Transportation attempts to do this in several ways. All formal recommendations resulting from research are made directly to the chief engineer or deputy commissioner, who is responsible for seeing that the recommendations are implemented or that there is justification for not implementing them. Reports are not merely sent to operating personnel with the hope that the recommendations will be put into practice, because operating personnel are swamped with the day-to-day job. There must be an orderly channel for consideration of research findings, and to accomplish that the responsibility has been placed with the second-ranking executive in the department.

That is as it should be. Management has a direct administrative role in ensuring that appropriate research results are put to use. Employees are encouraged to understand the value of the research program by becoming participants. Approximately 100 take part regularly in the guidance of research efforts and the implementation of research findings through at least 12 advisory committees.

The foregoing observations, by implication, obligate management to funding its research program. However, it is well to avoid budgeting all research funds directly for specific projects. In Virginia, a substantial amount is left flexible to accommodate unforeseen, short-term projects and to allow the research staff, at least to a limited extent, to initiate projects for which it perceives a need.

Research and development should have a practical application, but they should also address something more than after-the-fact problems. Indeed, not all research activities should be problem-oriented. Some must be visionary and, ideally, solutions should precede problems. If the research staff understands that management is looking for useful results, then a degree of freedom should be permitted for the research group to select projects. If management is committed to the desired level of support, is it not appropriate for management, in turn, to look to the research group to assist in identifying and pursuing original and practical ideas that will benefit the organization?

There remains at least one further management responsibility, that of evaluating research efforts. Sometimes it is difficult to evaluate the program solely on a dollars and cents basis, and it is probably best to look for some other type of measurement. The truest test, of course, is to be found in the extent to which research results are used. A simple listing of those results that have been implemented, together with a listing of the research costs, is a helpful method. Dollars saved is a valid measurement; however, it is far from a complete one because it overlooks the public service benefits.

When Virginia had a visibility problem during periods of heavy fog on the I-64 crossing of the Blue Ridge Mountains, the research council was asked to find a solution. It developed a project for the installation of high-intensity airport runway lights in the roadway edge. Although the system has not been entirely trouble-free, visibility for motorists has improved significantly—

and that was the first objective. To evaluate that project in monetary terms would be erroneous, because its fundamental value was in providing higher levels of safety, to say nothing of higher levels of motorists' peace of mind.

When the department wanted to evaluate public participation in the planning process, it again turned to the research council. And the council produced recommendations that dramatically improved the conduct of public hearings. A financial yardstick cannot be applied to that effort either. But the benefits are apparent.

In a more general sense, it is appropriate for management to periodically assess all programs of the organization, at least to match performance against expectation. That is simply good administration, and it can be done with the research program as readily as with most other functions. In such a process, if a program is proving its worth, the assessment almost certainly will lead to renewed and often to a heightened expression of management approval and support.

Clearly, management has a leadership role if the research program is to be effective. Management must demonstrate by its attitude that it recognizes the importance of the program. It must assist in setting the goals and objectives and in integrating the research function into the total organization. The credentials of those engaged in transportation research are too strong, their contributions are far too evident, and their place as members of the transportation team is much too vital for there to be any doubt about management's proper role.

Development of Multidisciplinary Research Programs

Martin Goland, Southwest Research Institute, San Antonio, Texas

High-technology goals require the focusing of varied skills on chosen targets; thus, the need for a multidisciplinary attack on most modern research and development programs is obvious. The multidisciplinary approach means the mixing and coordination of ideas and capabilities derived from a variety of professional backgrounds. The barrier of the organization chart must be overcome. Because organization charts define boundaries of responsibility and lines of authority, they complicate the process by which ideas flow from one segment of the organization to the other, with deadening effects on multidisciplinary cooperation. Although each of the institute's operating divisions has its greatest strengths in certain disciplines, we encourage creative thinking that leads to entry into new fields. The institute structure is designed to combine the advantages of line responsibility that reside with our vice president with the benefits that come from multidisciplinary, multidivision collaboration. Although not without difficulty, we manage to achieve an effective balance between the two.

Applied research and development is aimed at the translation of fundamental research results into useful products and processes and the exploitation of new and inventive concepts. Particularly where high-technology goals are involved, what is needed is the focusing of varied skills on chosen targets. The carrying of a technological option through its various phases from inception to demonstrated marketability usually requires blending the talents of scientists, engineers, production specialists, economists, and others. The need for a multidisciplinary attack on most modern research and development problems is obvious. In the commonly accepted definition, the multidisciplinary approach is a consequence of the mixing and coordination of the ideas and capabilities derived from a variety of professional backgrounds.

There is another kind of multidisciplinary strength in a research and development organization that is often not thought of in these terms; that is, the innovativeness and fresh insights that come from technology transfer from one market sector to another—the recognition that ways of accomplishing objectives in one field of activity are applicable to other fields as well. The most notable and publicized examples are the spin-offs from national defense and space programs to the private sector.

Historians of science and technology pursue their subject for many reasons, but certainly one of the more important is to attempt to understand how new and creative ideas come into being. On one point there seems to be general agreement: Significant advances do not often come as the result of a planned program for discovery. Rather, they arise from a conceptualization of the problem that departs from the traditional mode of thinking and that changes the very way in which the problem is approached. Newton had before him the same facts that were available to Kepler and to other natural philosophers who attempted to understand the motions of the heavenly bodies. Newton's flash of insight was the recognition that the instantaneous observations of position in space and time are less important than the rates at which these variables change. From this came the concept of the mathematical differential, and from this was born the calculus.

In a similar way, the contribution of the Wright brothers was not in their refinement of values for the aerodynamic coefficients for lift and drag as a function of angle-of-attack. Rather, it was their recognition that the essential barrier to successful flight was the ability to exert control in flight, the capability of overcoming disturbances that arise from wind gusts and other unexpected sources through direct pilot action in a practical way. Lilienthal, the German experimenter, had attempted to do this by pilot gymnastics, which shifted the locations of the center of gravity of the craft, and he failed. The Wright brothers conceived the idea of wing warping and culminated 100 years of striving by others with their own success.

One of the most important responsibilities of the research manager is to encourage staff to engage in speculative thinking. This is sometimes accomplished by bringing together the viewpoints and insights from multiple disciplines; at other times, the route is through the association of ideas drawn from neighboring technical areas; and occasionally it is the result of the flash of insight that comes to a talented staff member.

At Southwest Research Institute, we create an environment that encourages a multidisciplinary, associative approach to new problems. In common with the other private, nonprofit institutes, our charter requires that we provide a broad research and development service that supports and contributes to the technological advancement of industry, commerce, and the government. Accordingly, each of these institutions is characterized by a wide spectrum of disciplinary capabilities, ranging across the physical sciences, chemistry, various branches of engineering, biology, economics, and, in some instances, the social sciences and management. Projects are undertaken for virtually every sector of industry and government; in our own case, more than 500 projects are active at any one time for more than 300 different clients. The opportunity for cross-fertilization of ideas and experience in the full multidisciplinary sense is thus ingrained in the very texture of our daily operations.

Nevertheless, an effective multidisciplinary operational mode in an organization of appreciable size does not occur naturally. Management must be continually alert and dedicated to reducing potential barriers, and the complexity of the management problem multiplies with the size of the organization.

To begin with, the organization chart barrier must be overcome. There is no question that every enterprise of any degree of complexity must accept the burden of the bureaucracy that flows from a piece of paper imprinted with numerous boxes interconnected by lines. Although the organization chart for a research and development enterprise often has a sophisticated underlying philosophy as its basis, the bureaucratic backwash is inevitable. Because organization charts define boundaries of responsibility and lines of authority, by their very nature they are vulnerable to complicating the process by which ideas flow from one segment of the organization to another. The influence of such rigid delineation of responsibility on multidisciplinary cooperation can be deadening unless the issue is dealt with seriously and with special attention.

A second problem is that of communication within the organization, which is a particularly difficult one for a contract research and development activity, such as Southwest Research Institute, that simultaneously serves a large number of sectors. If the purpose of interdisciplinary cooperation is to encourage innovative thinking by staff members who have diverse backgrounds, training, and skills, how can they all be kept aware of the technical challenges and the project opportunities that exist in areas outside those that absorb their immediate attention and to which they are capable of contributing? Equally important, how can staff members be motivated to take time out from their busy schedules to think about such matters?

Another area that requires constant attention is the selection of staff for projects to ensure a proper multidisciplinary balance. In recent years, the term "matrix management" has become a formal part of management vocabulary; it embodies the idea that a project manager should be free to recruit project staff from all areas of the organization in order to fill a needed complement of skills. The project manager thus works horizontally through the organization, cutting across the vertical structure that reflects the line-authority pyramid. In some organizations, matrix management works quite well; in others, it encounters difficulties.

It is axiomatic that long-range planning mechanisms for a research and development organization should place special emphasis on the multidisciplinary perspective. If the overall plan for the future is permitted to become an aggregation of goals independently established by the line elements of the organization, each characterized by a parochial point of view, the maximum benefits that can be derived from a broad, multidisciplinary approach will not be realized.

We have found that the most successful operating philosophy for the overall growth and development of the institute is to give each of our 11 operating technical divisions wide latitude and considerable autonomy in the conduct of individual programs. Each division is established as an independent cost center and, in essence, each is an entrepreneurial group that conducts its own business under the leadership of a vice president. Our senior management staff is small—the president and four corporate vice presidents (one financial) to coordinate the activities of more than 1700 staff members. We view the function of senior management as analogous to that of a holding company headquarters for a technical conglomerate. So long as a division's performance is in line with expectations, we leave it alone.

At first glance, our organizational philosophy appears to be the very antithesis of how to design a structure to encourage multidisciplinary cooperation. But this is not the case.

As the first step in promoting a multidisciplinary viewpoint in our project activities, we define the boundaries of topical coverage for our divisions relatively loosely. Although each division has its greatest strengths in certain disciplines and market areas, we encourage creative thinking, which leads to entry into new fields. We adhere to this policy even when it results in overlap between divisional interests. In some instances this leads to a spirit of competition rather than cooperation among our divisions. We accept a certain level of internal friction from this source and depend on our senior management to control and defuse such situations. Of course, organizational changes are a means of solution when all other efforts fail.

In the transportation field, for example, where the institute conducts a broad spectrum of project activity, the total program is currently dispersed among 10 of our 11 technical groups. One of the reasons for this wide distribution is our practice of informing all groups of project possibilities that flow from outside contracts and sources. Each division is invited to indicate willingness to participate in the framing of a program response. The final decision regarding which division will take lead responsibility and the definition of the roles of the various collaborating groups are decided in conference chaired by senior vice presidents.

Since many of our projects are relatively small in size and area extensions or offshoots of prior divisional activities, a large number are handled as single-division efforts. In order to ensure that the range of necessary talents is available, a flexible approach is adopted when it comes to disciplinary staffing within divisions. Within the bounds of remaining financially sound and within budget, each vice president is free to add scientists, engineers, and technicians to promote self-sufficiency of operations. The alternative organizational philosophy would be to staff our divisions along largely disciplinary lines.

Matrix management is used for larger programs and for innovative programs that tax the capabilities of individual divisions. Our means of employing this technique are relatively conventional; primary management responsibility is assigned to a project manager located in a lead division; collaborating talents from other divisions are assigned to the project staff according to predetermined agreement or as new project needs arise. Since bureaucratic or other organizational obstacles may arise in large matrix-managed programs to impede their progress, review meetings are held by senior management with project managers and key personnel at least four times a year.

The long-range planning strategy for the institute is shaped by a number of considerations, some of them special to our kind of organization. Since we are committed to serving a broad spectrum of industrial and governmental needs, the inflow of projects is to some extent a function of the demands placed on us by our clients. The levels of activity in different areas may increase or decrease; the current emphasis may be on longer-range research or close-in development. Counteracting these external influences, which if left unchecked would result in a highly opportunistic program, are the internal strengths we build into the organization through the planning process and its implementation.

Our internal planning channels the allocation of institute resources (such as staffing emphasis, facilities, and internal research funds) so as to emphasize the development of program excellence in selected target areas. A target area is characterized by offering rewarding research and development challenges to the staff; it is a field of current importance to industry or government, or it is a field we believe will become important in the not-too-distant future. It is an area with resource needs that the institute will be able to meet. Our goal in each target area is to become a recognized center of excellence on the national and international scene.

For each target area, a planning task force is appointed, consisting of key members of the technical staff and of divisional managements. The responsibility of the task force is to guide and coordinate the total institute effort within its range of interests. Accordingly, the membership is chosen on an institutewide basis and emphasizes the multidisciplinary viewpoint. Each task force meets at the call of the chairperson, and at least once each quarter it meets with senior management present.

Our task force structure is, in a sense, an extension of the matrix-management technique as applied to the conduct of specific projects. The chairperson of the task force occupies a position analogous to that of the project manager but, rather than being accountable for the well-being of a single project, the responsibility is to ensure that the total strength of the institute is joined together to achieve program excellence.

The institute structure is designed to combine the advantages of line responsibility that reside with our divisional vice presidents with the benefits that come from multidisciplinary, multidivision collaboration. Although not without its difficulties, we manage to achieve an effective balance between the two.

How To Get Commitment To Productivity

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To get commitment to productivity by subordinates, the first essential is that managers have positive assumptions about people that (a) work is natural for them, (b) they will use self-direction and self-control when committed to objectives, and (c) they are responsible. The second essential is for managers to make clear to their subordinates how their performance contributes to the mission of their organization. In this process there must be agreement on the basis for evaluating the subordinate's performance. The manager is responsible for carrying out this performance evaluation at designated times and for confronting substandard performance as soon after it happens as possible. Another essential for managers is that they support subordinates by providing needed resources, training, and their own time to employees when needed. It is recommended that managers give positive recognition to subordinates whenever possible. Managers must also manage differences by allowing subordinates freedom in achieving the results expected of them on their jobs within the agreed limits. Conflict must be surfaced and resolved in order to clear the air for honest problem solving. Finally, managers have to be willing to give the needed time for interaction with subordinates. The organization has the responsibility to provide the necessary management training to managers to enable them to carry out the management function in a competent manner and to achieve a commitment to productivity in their work force.

What is the meaning of commitment and productivity? These are key words in the effective operation of an organization. They are easy to talk about but often hard to achieve.

COMMITMENT

Dictionary definitions of commitment include a pledge to do something and a state of being bound emotionally or intellectually to some course of action. In other words, it comes from within (inner directed). I make the decision on what I am committed to do, and my decision is based on my value system—what is important to me. Each of us has different values and, consequently, different reasons for being committed to the same course of action.

It is necessary to accept this basis for commitment and to manage with this assumption about people. McGregor was talking about this when he identified two sets of assumptions about people and their relations to work. He labeled these theory X and theory Y (1).

Theory X assumptions are that people dislike work, have to be forced and controlled to work, and have little ambition. These assumptions are outer-directed, and control is external. These assumptions are in conflict with the premise that commitment comes from within a person.

McGregor's theory Y assumptions about people are that work is as natural as play and rest, that they will use self-direction and self-control when committed to objectives, and that they, under proper conditioning, will accept and even seek responsibility. These theory

Y assumptions acknowledge that commitment comes from within and that people are in control of their behavior.

I believe in the self-fulfilling prophecy that people will be committed when managed by a boss who makes theory Y assumptions and will have little or no commitment when managed by a boss who makes theory X assumptions.

PRODUCTIVITY

Commitment has to be to a course of action. Therefore, productivity has to be clearly defined and accepted by a person. Persons are productive when they are contributing to the mission of the organization (2, pp. 121-127). Consequently, each person in the organization needs to know how his or her performance is necessary to accomplish the mission of the unit, which is supportive of the organization's mission.

It is easy to be caught in the activity trap and not be productive. One may be busy but not productive, or one may be efficient but not productive or effective for the organization. The difference is that busyness may produce a large quantity of work, and efficiency may produce things done right, whereas productivity or effectiveness is doing the right things. This is not to say that efficiency is not important. Sometimes, however, it is necessary to sacrifice some efficiency to be effective (2, pp. 136-158).

In order that subordinates are clear on productivity, there must be agreement on what is acceptable performance. This is accomplished through the negotiation of standards of performance and criteria for evaluation between boss and subordinate (2, pp. 184-186). This will clarify the expectations that bosses and subordinates have of each other.

ACCOUNTABILITY

After expectations are clear and standards of acceptable performance are visible and agreed on between boss and subordinates, the boss has the responsibility to perform regular evaluations (progress reviews every quarter and a performance review once a year). Timing of these reviews may vary from one organization to another and from one individual to another (2, pp. 203-219). For example, it is necessary to review the performance of a new person on the job more often than that of an experienced person who is performing above standard.

Regular reviews will demonstrate to the subordinate that the boss is committed to productivity. At these review sessions, and particularly at the annual performance review, it is recommended that the boss give the subordinate his or her expectations of improved performance. It is well also that the subordinate identify areas for improvement. After these are identified, objectives can be set for the year or appropriate period of time. It may be necessary for the boss to commit organization resources in support of these improvement objectives, which may be in the area of skills, knowledge, attitude, and health. These developmental objectives are necessary to show the commitment of the boss and the organization to the individual. This is a strong message to the employee: You are good; you can do better; we expect you to do better and will support you to this end.

A manager is managing accountability when he or she is doing the above as well as confronting subpar or nonperformance as soon as possible after it is identified. The way that this confrontation is handled is crucial. A chewing out or a highly critical attitude on the part of the boss will not lead to commitment to productivity and improvement. It probably will lead to action by the employee to avoid getting chewed out in the future. This leads to defensiveness and commitment to survival with little concern for being productive.

A boss should confront the subpar performance with the expectation of a positive outcome, such as improvement in the future, a learning experience, and identification of what needs to be done to prevent a similar breakdown in the future. During the problem-solving discussion, the boss should ask the employee questions such as, "Was there something you needed from me that you did not get?" Or "What do you need from me to prevent this breakdown from happening again?" In this way, a boss is managing accountability and the helping relationship at the same time.

In addition, accountability must exist horizontally between team members and between units in the organization. Agreements on working relationships to be productive for the organization must be established, and when one party does not perform up to the agreement, the other confronts the nonperformance to solve the problem and lessen the chance of a repeat. Accountability works when one party, once aware that performance will be off, immediately notifies those affected and thus avoids surprises. Then there is an opportunity to problem solve and lessen the effect of the breakdown.

In managing accountability, it is essential that the manager have the positive attitude that people want to do well, want to contribute, and want to improve. With this positive attitude, results are usually good. Sometimes the outcome is not what is wanted or expected but what is appropriate. An example of this is that the employee may be in the wrong job, and then the next step is to discuss the employee's career and the type of work desired. This can lead to new duties, a new job in the organization, or severance from the organization and a different job elsewhere.

HELPING RELATIONSHIP

An important part of managing is the helping relationship. A boss must be supportive of staff and help them wherever possible. This help may be in the form of material or economic resources, problem solving, training, or education. The manager must be available to subordinates as a resource or as a person just to talk to occasionally. This concept of the helping relationship must not be confused with rescuing, or doing the job for the subordinate, or making the decision for him or her. The difference is that the help needed is defined by the subordinate and not by the boss.

An example of how this can work is when a subordinate brings a problem into the boss' office. If the boss solves the problem for him or her or takes over the task and does it, the boss is doing the subordinate's job. The message is clear that, "You cannot do it; let me do it for you." When the boss takes this alternative, the subordinate soon learns that the boss will do his or her job, and the subordinate becomes dependent and not very productive.

To avoid rescuing, an alternative that a boss may use when the subordinate brings in a problem is to ask, "What do you want to do about this?" or "What do you think we should do?" The subordinate generally has the solution but lacks confidence or may be afraid because of having been chewed out the last time he or she made a decision alone. It is recommended that the boss make an agreement with subordinates on what is expected from them in the area of decision making and problem solving and, at the same time, be available to help.

Another aspect of the helping or supportive relationship is complimenting (stroking) good performance and the things you want the subordinate to do more of. For instance, if a subordinate has difficulty in making decisions, compliment every decision he or she makes that comes out well, and for those that do not turn out well, problem solve for improvement in the future and compliment him or her on taking the risk. Of course, there are always limits, and the subordinate is accountable for staying within these limits, such as budgets, policies, laws, and safety.

Another aspect of the helping relationship is the willingness to give without expecting anything in return and to receive without feeling any obligation to give anything in return. It also includes the willingness to ask for help and to be willing to accept refusal.

DIFFERENCES

The way that a manager manages differences can be another key to commitment to productivity. Many people are frustrated by many unnecessary restrictions placed on them as to how they do a job. There is a tendency by some managers to force their values on subordinates. People are different and they have different values. Managers must be sensitive to these differences and allow subordinates to be different and to perform their job in different ways as long as they achieve the desired results within agreed limits. Often the results wanted by the organization are not negotiable, as are some limits; but there is usually considerable area for negotiation on how the results will be achieved.

People have values in the area of work on type of supervision, job freedom, money, type of work, and rules and regulations. For instance, the different values that people have on the type of boss they like are as follows:

1. One who tells employees exactly what to do and how to do it, and encourages employees by doing it with them;
2. One who is tough, but allows employees to be tough too;
3. One who calls the shots and is not always changing his or her mind and sees to it that everyone follows the rules;
4. One who does not ask questions as long as employees get the job done;
5. One who gets employees working together in close harmony by being more a friendly person than a boss; or
6. One who gives employees access to the information needed and lets them do the job in their own way.

A subordinate will be more productive when managed the way he or she wishes to be managed. A manager needs to first understand his or her own values, to be aware and sensitive to the values of others, and to supervise others in their value system, the way they wish to be supervised. Then there will be commitment. Being sensitive to the values of subordinates may require that a manager supervise different people in different ways. If the subordinate likes the supervision received and is productive, then that is the best way to manage that person.

Another aspect of managing differences is the handling of conflict. When there are disagreements or differences, these need to be discussed as soon as possible and resolved in order to clear the air for honest problem solving. Establish that it is all right to disagree and to have differences. After differences are vented, decisions are made and accepted, and people move on and produce for the organization. Things are working well when the employee is able to say, "We discussed our differences; I was heard; I do not agree with the decision. But I do accept it and will support it."

MANAGERIAL TRAINING

Managing for commitment to productivity as advocated in this paper may require new and improved skills on the part of a manager. If so, the organization has the responsibility to help the manager develop these skills. This is managing the helping relationship.

The skills that will be needed are in handling the communication process—interviewing, negotiating, evaluating, handling conflict, confronting, and complimenting. Other skills that may be needed are in the area of role clarification, developing standards of performance, and developing and using feedback systems. If a manager is expected to change the way he or she is managing, the organization has the responsibility to give him or her the training needed. Internal or external management consulting help should be available to a manager as needed to support him or her in changing managerial style.

SUMMARY

In summary, to achieve commitment to productivity the following are necessary:

1. The mission of the organization (and units within the organization) must be clear, visible, and accepted;
2. Assumptions about people must be positive (theory Y);
3. Individuals must be clear on what is expected of them on their jobs and how they are contributing to the mission, and standards of acceptable performance must be agreed on;
4. Accountability is managed; subpar performance is dealt with as soon as possible after being identified; evaluation is continuous through regular progress reviews;
5. The helping relationship is managed concurrently with managing accountability; people are complimented (stroked) for above-standard performance and desired behavior;
6. Differences in people are accepted, and people are managed the way they want to be managed;
7. Disagreement and conflict are surfaced, discussed openly, and resolved;
8. Managerial training is available to managers needing help in development of managerial skills and competence; and
9. Adequate time is given to the managing process, and open dialogue between managers and subordinates and between subordinates is expected and supported.

The accomplishment of commitment to productivity may require changes in attitudes and managerial philosophy. This change will require commitment on the part of management to provide the necessary resources and time. Managing change is a slow, deliberate process. The results will be rewarding to the managers, the employees, and the total organization.

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Scoping the Research Problem

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Scoping the research problem means defining the limits of a research problem. This paper presents an overview of the scoping function in the administration of highway research. The paper emphasizes the importance of team rapport for positive, productive research. The parameters of the scoping function are given. A practical example of scoping of research problems as practiced by the Mississippi State Highway Department is included.

Scoping the research problem is the defining of the limits of a given research problem. There are certain necessary scoping actions that overlap. There also is some of the scoping function in the research proposal evaluation. The scoping function is of fundamental importance in any research problem. It is evident that there is some overlapping in these related topics.

The successful scoping of a research problem requires a unique blend of administrative experience and a thorough knowledge of the organization's mission, resources, objectives, and personnel. It also requires technical skill and knowledge of the areas that require immediate attention through research. Most often, the task of scoping a transportation-related research problem is a team effort, consisting of, at a minimum, three key elements: (a) an administrator, (b) operations personnel who have a problem that needs researching, and (c) a researcher.

A high degree of rapport in this group is necessary for a successful research effort. The operations personnel has the problem that needs researching; the administrator knows the organization's resources that can be allocated to the problem at hand; and the researcher has the ability and knowledge required to do the work.

A great deal of thought, time, and effort is required to mesh what needs to be done into its proper relationship with the resources available for doing it. Almost always more needs to be done than there are resources that can be allocated to doing it. Here is where the rapport of the team can become strained and where, probably, the administrator will have to make a choice.

The responsibilities of the research team include the following:

1. The administrator has responsibility for research policies of the organization; knowledge of the organization's mission, objectives, and goals; resources (financial, personnel, and equipment); establishing avenues of communication; and getting research findings into use.
2. The operations personnel have responsibility for the problem that needs solving, gaps in the current state of knowledge that cause the problem, liaison with the researcher during the project, and recommending how research findings should be used.
3. The researcher is responsible for conducting the research; keeping the other members of the team fully informed of progress, problems, and findings; and writing the report in language that operations personnel can understand and use.

After the research team has identified what it considers to be a worthwhile problem, a problem that reasonably can be undertaken with the facilities available, the first level of its analysis will be in terms of its definition. This will serve to aid judgments as to its value and its feasibility.

What does the definition of the research problem mean? Obviously, it implies the separation of it from the complex of difficulties and needs in a given situation. To define a problem means to put a fence around it, to separate it by careful distinctions from like questions found in related situations of need. Monroe and Englehart give an excellent statement on this (1):

> To define a problem means to specify it in detail and with precision. Each question and subordinate question to be answered is to be determined. Frequently, it is necessary to review previous studies in order to determine just what is to be done. Sometimes it is necessary to formulate the point of view or educational theory on which the investigation is to be based. If certain assumptions are made, they must be explicitly noted.

The research team should perform the following in the scoping process.

1. The operations personnel must specify the problems; the limits of investigation must be recommended.
2. The researcher must know the current state of knowledge on the subject to test a hypothesis that has been postulated and to explain or predict on the basis of observed phenomena. He or she must also determine ways to make optimum use of the locality and facilities where the investigation can be conducted. The researcher looks to the phenomena brought up by the operations personnel and asks why, what, how, where, and when. When the researcher has completed all of this, and assuming that there is a problem, he or she will make comments and recommendations to the administrator as to where to install the fence for the research or investigation.
3. The administrator will make the final decision as to the location of the fence. Of course, he or she may also decide that no fence is needed for the proposed research problem because (a) in some cases, certain changes can be made in the management process that will eliminate the problem, (b) to solve the problem fenced by the researcher would exceed the financial capability of the organization and the problem would need to be refenced in smaller areas so research can get started, or (c) for the overall mission of the organization, this research problem does not possess a priority rating high enough to warrant immediate action. In this case, he or she may decide not to conduct the project.

Theoretically, this is how a research problem is scoped. It is appropriate to present a real-life situation and see how this procedure works. The Mississippi State Highway Department is small enough and its financial resources limited enough that it is blessed with a degree of flexibility and informality that enables the researchers to call on anyone in the organization for the information and cooperation needed to define a research problem.

The operations people have a problem that needs answers. The problem is referred to the Research and Development Division. This is done by memorandum or telephone. The first thing the researchers do after getting the problem is to discuss it with division staff members, as well as members of other divisions, to try to get a better feel and understanding of the problem. This process also has had a side benefit on several occasions. Often, the solution to the problem could be found by visiting experienced fellow employees. They have been able to provide the answer simply because they had been confronted with the same problem during their service to the department and found the answer by conducting their own research or by trial and error. Most of these findings were not documented. Therefore, when this occurs, the researchers always record the findings so they will be available in the future.

At the same time that the interdepartmental research scoping is going on, the researchers also perform a state-of-the-art search of the problem subject. Available for search and consultation are the experience, findings, and recommendations of others in TRB, the National Technical Information Service, Federal Highway Administration (FHWA) and U.S. Department of Transportation (DOT) publication program, FHWA National Evaluation and Experimental Program, FHWA Demonstration Projects, American Association of State Highway and Transportation Officials (AASHTO), and other state highway or transportation departments.

The researchers study the information in the literature to learn what research has been done in the area of the problem at hand. This takes time and is not easy. It is not often that one is able to find exactly what is sought in the literature. It happens, but not often.

Although one seldom finds exactly what one is seeking in the literature, it is almost always possible for an experienced researcher to use the literature to begin defining the scope of a research problem. Sometimes these findings of others can show what cannot be done or, at least, what has not yet been done; for example, preventing the accumulation of bird droppings on bridges. There is considerable material on this subject in the literature, but no completely satisfactory solution has been found.

Again, there may be much information available on a subject, but the researcher is then faced with deciding if the findings are applicable to a particular physical condition such as soil, temperature, rainfall, and elevation.

After the completion of this work, the research problem is presented to the Mississippi State Highway Research and Evaluation Committee for final review and comments before it is submitted to top management for funding consideration. The research and development engineer chairs the Mississippi State Highway Research and Evaluation Committee. It is composed of the heads of most of our divisions and the three assistant chief engineers, plus a representative of the FHWA division office. The committee meets quarterly and can meet more often, if necessary. There is a wealth of technical and administrative experience available to aid the researchers in finally defining the scope of any particular research problem of interest to the department.

Having defined the problem scope, and assuming that it meets the approval of the top management, the proposal is written, including the nuts and bolts of time, money, other personnel, equipment, and facilities. All that is necessary then is formal FHWA and Mississippi State Highway Department approval before work begins on the conduct of the actual research.

The FHWA, at least at the division level, and probably higher, has been in on the process almost from the beginning. As FHWA personnel do their job in the evaluation of the research proposal, certainly they also perform some function of scoping. However, the department's relationship with the FHWA, at all levels, has been outstanding and productive. All of Mississippi's research program is funded with Highway Planning and Research Program (HPR) funds, which means that the department almost always has to check with DOT every time a plan is proposed to do any research work. Only rarely is there a problem. For this, the FHWA people, at all levels, are due sincere thanks.

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Managing the Research Project

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This paper discusses the management of a research project from the perspective of an organized transportation research institute that operates within a major university. The management technique for a contract research project is described as a cycle of four formal evaluations superimposed on a continuous informal evaluation process. The basic objective, nature, and timing of each of the four formal evaluations are discussed as well as the categories of people that should participate in each evaluation. A brief description of the less formal but more continuous management evaluations associated with the management of projects within a cooperative research format is also given. The point is made that an important aim of the management and conduct of any research project should be to develop a close working relationship between the researcher and sponsor. This will make overall management of the project easier and will result in a better end product.

Research, to be efficiently and effectively conducted, must be managed. Whether management is formally organized or conducted intuitively by the principal investigator, it is critical to research performance.

I would like to address the topic of project management from the perspective of an organized transportation research institute operating within the framework of a major university. From this perspective, our view of research management may be slightly different from that of either the traditional academic-oriented research conducted by many universities or the private consulting firm. We are all seeking the same end product, but we may go about it in a little different manner.

To begin with, the management of a research project should be considered as a part of a continuous research management process that begins well before the individual project begins and extends through the publication of findings. The management of an individual research project is merely a part of this larger process.

The Texas Transportation Institute does research under two distinctly different contractual procedures: The research done through our Cooperative Research Program is for our state department of highways and public transportation and that done through the competitive proposal process has federal sponsorship. Let me begin by describing the management process for the contract research program. I will then try to draw some distinctions between this process and that used in the cooperative program.

As a general rule, transportation research takes on more of an interdisciplinary flavor each year. Research projects tend to be larger, and the number of different disciplines involved increases with the size and complexity of the problems being addressed.

CONTRACT RESEARCH AT THE UNIVERSITY

Interdisciplinary contract research in a university environment has special problems not shared by contract research firms on the outside or by those who conduct traditional grant research within the university. Contract research within the university must serve two masters. It must provide a usable product to the sponsor and also contribute to the educational objectives of the university. Without effective management and guidance, one of these objectives is often slighted. Research management at this level involves an evaluation of the research process as well as the product. In research evaluation, the appropriate questions appear to be the following:

1. Who should make the evaluation?
2. When should it be made?
3. What sort of things should be considered?

Evaluation, like project management itself, should be considered as a continuous process; however, there are really four times when a formal evaluation is necessary:

1. A "front-end" evaluation at the time the project is being considered,
2. A "start-up" evaluation at the time the project is initiated,
3. A "midterm" evaluation after the project is well under way, and
4. A "final" evaluation after the work is completed and a final report prepared.

There are also three classes of people who should be involved in these evaluations: (a) the research and university administration, (b) the research management, and (c) those who have technical responsibility for the conduct of the research.

Just who would be involved in each of these levels would vary from organization to organization and even from project to project, depending on the size, complexity, and number of different units or disciplines involved in the research. For simplicity, I will refer to the levels as administrative, management, and technical.

Now, as to what should be included in the evaluation—what questions should be asked and what assurances given—this, too, will vary with the time and level of evaluation.

Let us begin with a look at the front-end evaluation. This is primarily an administrative function and should be made at the time the research opportunity has progressed to the point of being given serious consideration but before a substantial investment has been committed to preparing a research proposal. At this stage the following administrative questions must be answered:

1. Does the research contribute to (or at least not detract from) the other academic processes of the university?
2. Will successful completion serve to enhance (or at least not detract from) the reputation and prestige of the university?
3. Does it offer an opportunity for faculty and student involvement?
4. What is the extent of the financial commitment required?
5. Is the research consistent with university policy with regard to such things as patents, publication rights, and secrecy?
6. Are there potential political impacts involved?

There is also a management evaluation that must be made concurrently. Here some questions may be the following:

1. Can we do it? Do we have the interested staff available? Is the funding adequate? Is the time period reasonable?
2. Do we have the physical facilities, offices, laboratories, and equipment necessary to conduct the research?
3. Are the technical expectations of the sponsor reasonable?

Now, assuming that the answers to all these questions have been favorable in the balance, that a proposal has been completed before the deadline, that it was judged technically acceptable by the sponsor, and finally, that you have had enough administrative flexibility and personal stamina to survive the rigors of contract negotiations, you finally have a contract. This may take anywhere from 2 to 18 months. After your principal investigator has regrouped the staff and they are ready to go to work on the project, it is time for the next evaluation.

The start-up evaluation is primarily a management review. Its purpose is to see that the proper institutional support is made available to accomplish the work and that the proper mechanisms are devised to ensure the continuity of the effort. Questions to be asked at this stage include

1. Do you still have a logical work plan?
2. Are all the staff times available in the amounts called for in the work plan?
3. Are there changes to the staffing or work plans that need to be negotiated with the sponsor?
4. Are the committed facilities still available and adequate?

It is important to ask these questions again at this stage because of the time lag between the preparation of the proposal and the initiation of work. Since we all live in a dynamic society, people who are named in the proposal and are expected to be available for the initiation of a new research contract may no longer be available six months or a year later when the project is awarded.

If we are to assume that an average of 10 proposals are received in response to each request for proposal issued, a success ratio of about 1:10 would be expected for the proposing organizations. Our organization is very fortunate that we have experienced a success ratio of about 40 percent. That is, we have been successful in receiving about 4 awards for every 10 proposals we submit in the competitive research field. Even with this higher ratio, however, we still face the problem of proposing to do more than twice as much work as we have staff capability to handle. This makes it imperative that the start-up evaluation be conducted in a rigorous manner and that project-life commitments be developed at that time.

The midterm evaluation is also basically a management review. Its purpose is to ensure that our original project team is functioning properly and that they are being provided with all the resources necessary to bring the research project to a successful conclusion. There is also a requirement to step back and make a technical evaluation at this stage. This is our last chance to ask questions such as

1. Is the proposed procedure still the favored approach, or have we found blind alleys and promising new avenues that should be discussed with the sponsor?
2. Are members of the research team staff technically competent and productive in this particular activity?
3. Has the staff developed a logical skeleton for the preparation of the draft report?
4. Is the project on schedule and within the budget? If not, what do we need to do to bring it back on track?

The final evaluation comes at the completion of the study. It is primarily a technical evaluation and is largely concerned with the final product—the final report. At this stage, the principal investigator and research management should have a debriefing as to how well the project team performed and what changes need to be made on future projects. Individual team members should be evaluated and special problems identified and recorded so that they can be considered on future projects.

The last element of project management is concerned with preparation of the final report. Until the final report is prepared, neither the research administrator nor the sponsor really knows how effective the efforts of the principal investigator have been in completing the objectives of the study. Indeed, within the framework that most of us operate today, our research programs are largely product oriented and, like the consumer product manager, our final product is the means by which our entire organization is evaluated. In our case, the final product is the research report. The sponsoring agency generally has already identified the problem, has often defined the conceptual approach to its solution, and sometimes has even outlined a proposed work plan that can be modified only within narrow limits. The professional performance of the researcher, then, is evaluated almost totally on the efficiency in the conduct of the research as measured by his or her capability in reporting research results.

In this context, the research report assumes an importance much greater than its real contribution to the total research effort. It becomes the sole visible evidence of the quality and thoroughness of the work performed by the research organization.

In order to ensure the quality of the final product, several years ago we established a series of report review teams to review each draft report prior to its finalization. This review team must answer three basic questions: Is the report technically sound, is it logical, and is it readable? The team is composed of three members. One member is from within the specific discipline or disciplines, one from the general field, and one from completely outside the field. For example, a report on freeway corridor control may be reviewed by a panel composed of a traffic engineer, a geometric design engineer, and an economist. The traffic engineer would evaluate technical quality; the geometric design engineer, the logical presentation; and the economist, the readability and the general sensibility question. Each member, of course, would also have responsibility for suggesting organizational and editorial changes that would improve the overall report.

As the report progresses through each stage of preparation by the principal investigator, it is reviewed by the program manager responsible for that area of research. At this stage most technical, organizational, and editorial revisions are made. A draft is then prepared for internal review. Three copies are submitted for concurrent review by the internal review team not less than 10 days prior to the date the report is due to be mailed to the sponsor.

Members of the review team are expected to complete their review within five days and submit their marked drafts back to the principal investigator. In instances where substantial comments are involved or major changes suggested, a review conference is held between the reviewers and the principal investigator. The principal investigator is expected to give full consideration to the comments received. He or she does not have to accept them all, but he or she is expected to give them professional consideration. Any irreconcilable differences between the reviewer and the author are called to the attention of the administration for further review.

We recognize that this is not a perfect solution and that the very nature of interdisciplinary contract research will make a perfect solution impossible to find. The time constraint alone is such that only a minimum amount of project effort can be devoted to the preparation of the final report. In no funded research programs that I am aware of is there a contractual provision for internal review prior to the submission of the draft report. The tendency seems to be toward larger projects, incorporation of additional disciplines in the research, and a reduced time period for the conduct of the work. Each of these makes report preparation more difficult and review more necessary. I would like to see at least a two-week internal review period incorporated into each contract to provide an opportunity for a realistic review prior to submitting the draft report to the sponsor.

THE COOPERATIVE RESEARCH PROGRAM

In closing, let me say a few words about the Cooperative Research Program that we have developed during the last 25 years or so with the Texas State Department of Highways and Public Transportation. In many ways the management of this program is more comprehensive but less formal and less complex than is the management of our contract research projects.

Over the years, our staff has developed a close working relationship with district engineers and division heads in the department. Each fall we begin a series of meetings in which the major problems of the department are identified and agreed on between our research staff and the responsible districts and divisions. Research problem statements are developed and priorities set by the four departmental area research committees.

In the winter of each year, these priority statements are presented by the area committees to the department's research and development committee and a departmentwide priority list is prepared. During the spring, individual research projects are then prepared under the guidance of the department's research engineer. By the beginning of the summer, both we and the department know the overall size of the next year's research program; its division into individual research projects; the staff, laboratory, and other resource requirements; and the timing of the research activities.

Through the continuous interaction of our research staff with the field engineers and administrators of the department, we are able to make most of the management evaluations informally and more thoroughly as the program develops. Consequently, by the time the project is initiated, most of the questions concerning staff, laboratories, work plans, and resources have already been answered.

I realize that it is not practicable to use this approach in contract research. I do feel, however, that anything that will bring the researcher and those responsible for research initiation closer together in an atmosphere that will promote a better understanding of the research problem areas, priorities, expectations, and limitations would add greatly to the efficiency of research and allow us to deliver a better project at a lower overall cost. It would also make the research project more realistic and easier to manage.