Transportation Research and Its Link to Education

Robert E. Paaswell

Research is conducted to advance our state of knowledge on topics about which we are concerned. Transportation research, in particular, seeks answers to questions, theoretical and applied, concerning the way we move ourselves and the objects we work, live, and play with.

We live in a technological society. If we have a problem, we create a solution. For example, after World War II we understood the incredible drive for mobility in this country and we created the Interstate highway system--one of the engineering wonders of all time. The creation of the system was conducted with little research. Since construction of the system we have spent billions of dollars on understanding all the implications of that creation. Perhaps the highway system, in all its magnitude, can serve as a metaphor for transportation research. It combined short-term demands with long-term implications: it attempted to apply the most practical of solutions to all its elements while raising elements of the most theoretical type.

Why conduct research in transportation? People have always sought mobility and, not being individually self-sufficient, must also have ways to move goods. Transportation research at its most general level seeks answers to the following questions:

- What are the most efficient and effective ways of moving people and goods?
- How can the greatest benefits be derived from our means of transportation?
- How can the costs of providing transportation continually be reduced?

There are a number of corollaries to these questions.

- How can we move people and goods as quickly as possible?
- How can we move ourselves and our goods as safely as possible?
- How can we minimize the obtrusiveness of our transportation systems on our overall environment?

Social values, at various times in our history, have placed differing emphasis on these questions. Before we were concerned with the environment, we conducted research on highway safety and traffic flow, and, as a result built immense highways and interchanges for high-speed operations. We then followed with research in the land use impacts (dislocations as well as development) of these enormous pieces of construction.

Research in transportation arises as solutions are sought to urgent problems. The form the research takes, its scope, content, impact, utility, and the dissemination of the results are determined by the person that defines the research problem. Research can be theoretical or applied, can deal with issues in the short term or long term, can be elegant or quick and dirty. We are learning now that the breadth of research, especially university-initiated research, is determined to a great extent by the sponsor of the research. Such research problem formulation leads to some difficulties, yet it may also spur innovative solutions to problems by using approaches and mixes of disciplines not thought of 20 or 30 years ago.

Only one major aspect of transportation research is addressed in this paper--that research conducted at universities and colleges. Examined are

- The objectives of transportation research,
- The conduct of transportation research in an academic setting,
- Aspects of research needs and support, and
- The future of academically based university research.

Transportation research comes in many modes and disciplines. This paper is directed to highway and transit research and deals with research as viewed from a U.S. perspective.

OBJECTIVES OF TRANSPORTATION RESEARCH

Some of the objectives of transportation research are to

1. Solve a well-defined problem for which an immediate answer is needed (e.g., impacts of transit fare increases).
2. Help define the ranges and limits of a problem (e.g., land use impacts).
3. Synthesize or gain understanding of previous history in an area (e.g., behavior of fills in marshy areas).
4. Postulate new methods to address defined or emerging problems (e.g., travel demand).
5. Suggest new subject areas or approaches in a speculative way (e.g., communications; innovative propulsion systems).

To accomplish these objectives, organizations carry out a variety of studies, or research projects, of varying intensity and length and propose conclusions or findings. Transportation research is initiated throughout the transportation industry, in public and private sectors, in small and large firms, and throughout every level of government.

For the purposes of discussion, I propose that three basic organizational institutions are responsible for the conduct of research:

1. In-house research groups--part of the organization that identifies the problem and seeks the solution.
2. Consulting organizations--both profit and not for profit (both in-house groups and consulting organizations might include vendors of transportation equipment).
3. Educational institutions.

Each of these organizations is unique, with its own internal organizational requirements (Table 1). The problems addressed by each organization do not fit into simple categories, but these definitions outline the traditional roles.

What, then, is the appropriate contemporary role of university-based research? How can it (or should it) sustain its inherent uniqueness? What contributions can it make?

TABLE 1 Institutional Research Organizations

Organization	Characteristics of Research
In-house agency (non-research and development)	Part of firm or public agency; problems often short term, applied research orientation; quick solution with operational outcome demanded; problem payoff must be found; staff not necessarily full-time research staff
Consulting firm	Usually permanent capability in a defined area; responsive to client needs; fit research approach to client resources; able to produce intense levels of effort over specific time spans
Educational institutions	Multidisciplinary staffs with continuity of effort; more responsive to long-term problems; training of future professionals part of overall research effort; applications of state-of-the-art thought to problem solution

Theoretical Versus Applied Research

Academicians have the mandate to advance the state of knowledge in a given discipline. Traditionally, university research has been coincident with theoretical research. Theoretical research poses theories and hypotheses concerning behavior. Excursions into entropy theory, or utility maximization for travel demand analysis, or the application of the theory of elasticity to layered system theory for soil foundations have been primarily university contributions. Universities have the resources and the time to experiment and to postulate related problems, and they also have the luxury of trial and error that other organizations do not. Theoretical research implies postulation and experimentation while simultaneously demanding rigor. The nature of theoretical inquiry is one of the products that is given to young researchers (often graduate students) as they conduct research in an academic setting.

Applied research is more problem specific than generic. It seeks solutions to (not always) well-defined problems, and, as a product of the research, seeks prescriptions for the solution of problems. Examples of applied research that have a broad impact on transportation systems are the development and integration of the stress-path method into analysis of foundation structures (retaining walls, stability of embankments) and the new application of the development of new software for microcomputer applications in all aspects of transportation.

Applied research in a university setting should have a product that is meaningful in an academic context. Universities, in general, do not usually compete

with consulting firms or testing laboratories for routine analyses, data collection efforts, or standard tests. The implication of applied research being conducted at universities is that the perspective of or approach to the work is unique, the information gained advances the state of knowledge, even if by a small increment, and the results can be published or presented.

RESEARCH IN AN ACADEMIC SETTING

The university provides a special setting for the conduct of research (Table 1).

1. Continuity. Universities are long-lived, generally conservative institutions. The structure and conduct of work at universities can generally be predicted, although the personnel might change. Disciplines develop and evolve, information is shared with colleagues, and program content is established; this is critical. The work of a faculty member spans teaching and research; there are no sharp divisions. The impacts of research find their way into a teaching program and are passed to a large number of students. Simultaneously, methods and theories tested in the classroom find their way into the operations of a research project. The method, or approach to work, is somewhat consistent across universities. The client can anticipate, now, or next year, how work will be conducted and disseminated. This continuity of approach is complemented by a continuity of content. In terms of continuity, this means that knowledge gained previously from a study can be tapped in the future, and information transfer (through students) will continue.
2. Discipline range. Universities, by their design, incorporate a wide range of disciplines. In innovative approaches to research, these disciplines can be brought together. This discipline mix can be brought about because the talent is in-house, and as a result of program continuity, will remain in-house.
3. Students. Universities involve students in the conduct of research. Students, imbued with the cutting edge of knowledge, are true apprentices to the discipline. Working on master's theses or doctoral dissertations, under supervision, they can apply dedicated time, energy, and intellect to the in-depth solution of a research problem using the available university resources. Dedication to task and freshness of approach often lead to insightful, well-constructed research, while it simultaneously prepares the student, through the learning of methods of problem solving, for entry into the profession.

MEASURES OF RESEARCH SUCCESS

The success of research efforts at institutions can be readily measured. There are traditional academic standards that can be used to evaluate research. In addition, there are new standards evolving, which might, if unchecked, change the nature of inquiry at academic institutions, and not necessarily for the good.

Traditional measures include

- Program output and growth;
- Development of new, utilized methodologies;
- Infusion of new knowledge in program;

* Application of research results by profession with measured results; and
* Prestige of faculty.

New measures include

* Ability to patent, sell, or lease direct products or by-products of work; and
* Dollar value of research support.

A successful research program is one in which real solutions to the problem studied can be observed, milestones of success measured, and positive responses to the work forwarded from outside the institution. Through the stimulation of faculty interest, student interest is increased. Successful research programs act as magnets for students and faculty, and this in turn helps program productivity and sustains success.

Measures of success in transportation are also provided by dissemination and use of the research products. The dissemination is seen not only in textbooks and technical papers, but also in reports of on-line use by transportation agencies.

Institutions change, however. Many institutions now measure success principally in terms of external dollars of research support. Although in one sense this can be considered an incentive, a lessening of true academic research can result from an institution making dollar values of research the primary goal. That this has become an academic way of life has had a dampening effect on transportation research.

Successful research programs stimulate faculty interactions and foster a continuity and growth of institutional transportation activities. In the next section the format and context of research in an academic setting is discussed in more detail.

CONDUCT OF RESEARCH AT A UNIVERSITY

Research organization and management has the following components:

1. Identification of a problem,
2. Organization and management of people and equipment to approach the problem, and
3. Dissemination of research results.

There are a number of organizational approaches to research. These are given in Table 2. Table 3 further delineates the participants in the research process. Although a solitary researcher working on a problem in an office or a laboratory is considered to be the traditional academic approach, it is more likely that a transportation researcher will be part of a faculty-student group or a team. The researcher, however, will contribute a specific area of knowledge. In academic research it is often expected that each member of the team or group will make a significant (and publishable) contribution to the research being conducted. The products of academic research are often technical papers of two forms: papers internal to the project--working papers and interim and final reports and papers for publication in technical journals.

TABLE 2 Methods of Conducting Research in Academic Settings

Type of Research	Approach
1. Single faculty, unsponsored	Faculty member defines problem, addresses to his or her perspective, writes technical papers and reports as part of academic load, or on own time.
2. Single faculty, student support	Faculty, as in item 1, defines problem, has internal or negotiated external support for student(s), graduate or undergraduate, who conduct background research on problem. A variation of this is thesis or dissertation prepared by student under supervision of faculty, and the topic is selected by faculty (student or university is source of student support).
3. Single faculty, sponsored research	A faculty member conducts a research study that he or she proposed to a sponsor in response to a problem delineated by a sponsor, or that is on a negotiated topic. Support is provided by the sponsor for a portion of the faculty member's time, student support, and other essentials of the work. Products of the work (reports, test procedures, equipment, etc.) are often specified, and the time of delivery of the reports is often specified.
4. Multi-faculty sponsored research	Essentially the same as item 3 except additional faculty from one or more academic departments are involved, and the project level of effort is greater.
5. Research centers or institutions	Umbrella organizations for campus-wide transportation programs; centers play many roles. They can provide a large-scale link from the university to the professional world, represent a wide variety of disciplines, and provide the resources for seeding research studies and supporting students.
6. Consortium	Inter-campus groups have the ability to pool, or build on single campus capabilities. This might provide a sponsor formidable groups of faculty who can bring a wide array of talents to bear on a particular problem. Students would benefit by enlarging disciplinary contacts different from their own contacts.

TABLE 2 (continued)

Type of Research	Approach
7. Fellowships, exchange	Academic faculty are sometimes presented unique opportunities to increase their own knowledge through concentrated study in a particular research area. Fellowships that permit devoted study on the faculty's campus, on an exchange campus, or in a federal or private agency are examples of this type of external support.
8. Student fellowships	Some agencies provide opportunities for students to work on research projects either on campus, or at the agency location. These fellowships may also stipulate that a faculty advisor be associated with the project.

TABLE 3 Principal Personna--University-Based Research

Participant	Research Process
1. Faculty member	The university professor is at the heart of campus-based research. The link between the research, acting as principal investigator or faculty associate, or project consultant; defines, or helps define the scope of the research, is responsible for its intellectual content, is responsible for the methods and procedures of the research, and is responsible for the products of research. Further, the professor has the additional responsibility of integrating the knowledge gained in the research into the content of his or her teaching; this is where the growth and dissemination of new ideas really takes place.
2. Student	The student is the first in a line of beneficiaries of the research. By going through all of the steps of the research process, students form habits of problem examination and solutions that will remain with them throughout their careers. The student represents, therefore, not only the professor's thinking, but the next generation of approaches to research and problem solving. Although this may seem an ideal, it is an important concept of academic-based research.

TABLE 3 (continued)

Participant	Research Process
3. Sponsor	The sponsor underwrites research projects through the allocation of resources to the campus where it wants the work to be done. The sponsor can be relatively uninvolved in problem selection (National Science Foundation or a state research board) or can define a problem extensively and fund those it believes provide the best approach. The sponsor has the ability to define the scope of a project, in any instance, through the magnitude of resources applied to the problem. The nature of these resources most often takes the form of a project budget.

There is one other aspect of published research unique to universities--the student master's thesis or doctoral dissertation. These serve a number of purposes. First, they train the student in the methods and rigors of research. Second, they enable the student to focus on a problem in detail, and help the student become a resident expert in a given area. Third, they enable the student, a fledgling professional, to make a contribution to the field, through a well-written treatise. The transportation profession trains and disciplines its future leaders through this process. The more attention paid to the graduate education process, the more rewards will be reaped from it.

Another method of dissemination of research is to present talks and discussions at professional meetings, conferences, technical briefings, seminars, and workshops. This is an excellent method for rapid dissemination of work in progress, recently completed work, or even forums for the initiation of new ideas. Major congresses provide opportunities for cross fertilization of new ideas and approaches, and often serve to inject new directions into research programs and new ideas into academic programs.

It should be noted that in recent years there has been a professional outcry that the academics are monopolizing many of these conferences and meetings, to the dismay of practitioners. Many academics have responded by directing their research, or research products to a more applied outcome. Before I address this issue, which I believe to be one of the most critical in assessing the future directions of academically based transportation research, it is necessary to discuss how research needs are generated and the influence of the sources of research support.

IDENTIFICATION OF RESEARCH NEEDS

The proliferation of transportation journals, conferences, and meetings would convey the appearance of unsatiated research needs in transportation, limitless resources to work on the problems, and growing numbers of academics making transportation a career. Yet we are at a significant crossroad in transportation education. Academic programs and student demand are shrinking, and sponsored research, especially at the federal level, is also shrinking. The problem areas the current generation of tenured (senior) faculty learned and worked on no longer

appear to be the critical areas. Where, then, is the audience for the products of our transportation research?

Statement of Needs

Research is driven by the inquiry into what makes things happen. Applied research further asks how can things that behave poorly be made to behave better. Transportation as a discipline is primarily an applied discipline. Those seeking solutions to existing problems far outnumber those asking the more general whys. This masks the strong need to establish valid theoretical approaches to transportation problems, theory that may help deal with the short-term problems as they continually arise. The needs statements that are developed today are more in response to improving our given systems than in questioning future transportation requirements.

Needs statements are generated by

- Institutions and agencies outside academia,
- Faculty members, and
- Students.

The institutions that identify needs include federal agencies, state and local agencies, the National Research Council, and some private organizations, firms, or foundations.

In the areas of highway and public transportation, the U.S. Department of Transportation (DOT) and state agencies have had more influence on the direction of research at universities than any other sources. In the last 5 years, these needs have become very short run and pragmatic. Both federal and state agencies appear to be faced with extensive problems that demand immediate attention, and both appear to have few resources to deal with them.

Needs statements are often turned into research programs. There have been two major dedicated university programs at DOT; the Program of University Research (now in the Office of the Secretary) and the UMTA Program of University Research and Training. Both programs generate needs statements through solicitation from DOT program offices. The needs statements reflect current-year DOT policy needs. Programs officials do not have interplay with outside personnel (including academics) in preparing the statements. The statements are often extremely applied, lend themselves to a narrow problem or project, and have a short period of investigation and interest. This process of needs identification, conducted on a yearly basis, does not lend itself to the development of programs at institutions through continuity of funding, or breadth of approach. A better model of the latter was the earlier UMTA program grants, or the current UMTA centers grants that promote continuity.

The National Cooperative Highway Research Program and the National Cooperative Transit Research Program are also project oriented, and address specific issues that individual states identify. Clearly, these agencies that set major transportation policy assume that academic institutions can be participants in research, yet they abdicate the role of helping formulate and underwrite academic research policy directions.

DOT has, in the past, published national priorities, or agendas for transportation systems. The identification of such agendas, again, should serve as

stimuli for research in those problem areas. The current federal position is to delegate the generation of transportation needs statements to the states.

The dilemmas we face today arise, not because we have no sense of need or priority in transportation, but because the setting of major priorities in research is decreasing at the federal level, and the slack is not being taken up rapidly at other levels. University researchers, in the past 5 to 10 years, in all but a few instances have served as reactors--reacting to stated needs and matching talents to formulated programs. These programs, however, had short-term objectives, were extremely applied, and were often narrowly focused.

There are two major points to be gleaned from this. The first is that federal mission-oriented programs have made faculty groups focus on applied programs and develop capabilities to respond to those program needs. Certain universities have developed capabilities in such areas as transit operations, transit maintenance, paratransit, safety, traffic engineering, and rural transit. If universities develop critical skills in transportation programs, that is, groups of faculty who have complimentary skills to deal with the research areas, these skills can be expanded in the area of research or begin to approach other areas of interest. This is the ideal situation, where a research program stimulates growth. In the case of less than critical mass (one or two faculty members), pressures for research support might cause the faculty to shift from area to area. Lack of continuity of research direction or support might hinder mature development in a specific field.

The second point is an emphatically positive point. University researchers have shown not only the ability to respond to federal or state research programs, but they have made significant contributions. Universities have always taken the lead in the development of analytic techniques for transportation system analysis. But they also have developed innovative approaches and solutions to problems such as:

- Services to the elderly and handicapped,
- Stress and strain instrumentation of highway-related structures,
- New standards for highway capacity, and
- Information concerning child safety in automobiles.

In summary, transportation research needs, although often articulated by university researchers, are not always adapted by sponsoring or policy-directed agencies. Transportation system needs and their related research and development agendas are set by federal, state, and local agencies. These agencies are extremely conscious of the scope of the problems they must work with and the limited resources to solve those problems. Hence, in recent years such agendas have become very short term and quite specific. Further, the setting of such agendas has shifted from national policy to state policy. Universities have shown a continuing ability to respond to such programs, but have done so at some costs to program expansion and continuity. Further implications of the sources and levels of support are given in the next section.

SUPPORT OF RESEARCH

University research is supported in two ways: external support, that is, funds from sources external to the university acquired to support specific research,

and internal support. Internal support, in its simplest form, is the university support of a faculty member in his or her research work. Such support can take the form of time away from teaching activities for research activities, or it can be internal academic grants to support equipment, computer time, travel, summer support, and student support.

In an active research program, there must be a balance between the two. As an example of the levels of support, a budget is given in Table 4 for a typical research project involving one faculty member (at 20 percent of the academic year, in days per week, and 2 months during the summer).

TABLE 4 Costs of Research Support (dollars)

Cost of Typical Research Projects[a]	
Faculty member working 20 percent of academic year, on study 2 months during summer	
Graduate students 50 percent academic year, full-time during summer	
Salaries and wages	
Principal investigator: 20 percent (35,000) + 2 (35,000/9)	= 15,000
Graduate assistants: two at $10,000	= 20,000
Secretary: 10 percent (15,000)	= 1,500
Fringe benefits 15 percent of salaries and wages	= 5,500
Supplies	= 1,000
Travel (visits with sponsor)	= 1,000
Computer (some cost sharing with university)	= 500
Subtotal (direct costs)	= 44,500
Indirect costs (65 percent of direct costs)	= 29,000
Total	= 73,500
Person years = 1.4 per years	
Budget = $52,500 per per person year	
Graduate student assumed at $10,000 per year (50 percent time academic year, 100 percent summer)	
Faculty salary assumed at $35,000 year (academic year) (9 months)	

Note: Overhead at 65 percent; fringe benefits at 15 percent.

[a]A faculty member at a research university might spend 50 to 75 percent of his or her time on research activities, some funded, some unfunded. This budget shows the allocation of time to a particular project, but does not account for 100 percent of the faculty member's time.

To conduct a research project of this magnitude, a faculty member might seek support from a number of sources. Often the faculty member will seek external funds from an identified program for all or most of the budget. Quite often a university is asked to cost-share, that is, to provide some of the support for the research. In a university that is research-oriented, such assumptions by the sponsor that a university should cost share are legitimate.

Currently, there are few federal programs targeted to universities by DOT for the support of research. Those that are active and their funding levels are as follows:

- DOT, Program of University Research, Office of the Secretary, $800,000 for minority institutions.
- UMTA, Program of University Research and Training, $2,000,000, of which $1,000,000 is targeted to ongoing centers programs; $200,000 to the Summer Faculty workshop leaving $800,000 available for open competition.
- Maritime Administration, $500,000.

Each of these programs supports research projects for which specific delivered products are required; often final reports are required after 1 year of work.

Examining the implications of these budgets, it can be observed that in a typical budget year, DOT funds $3,300,000 targeted to universities. This amount of funding supports approximately 45 research projects, or 90 graduate students. This is certainly an inadequate base of support from which to provide a steady supply of well-trained future professionals to the disciplines.

Thus, faculty seek other sources. First, they might compete with consulting firms for other federal contract research. Second, they may approach the National Science Foundation (NSF). However, only since 1983 has NSF recognized transportation research as a program area. Some support has been available for civil engineering, or economics and geography-related projects. The entrance of NSF into the funding arena, however, is a significant and primary sign for the rest of the 1980s.

Faculty also look to state agencies for support. Successful partnerships have been forged in Texas and Indiana with state transportation departments and universities, but these close working arrangements are the exception rather than the rule. Too often states conduct in-house research themselves or do not pursue research activities. Rather, they seek answers to highly applied, short-term problems. Agencies are reluctant to contract with universities because of what are stereotypical attitudes toward the ability of professors to visualize and deal with problems as the state agencies define them.

This dichotomy between many state agencies and universities must be resolved if academic research programs are to be revitalized. States will assume a greater role in research as the federal government continues to relinquish that role.

The dichotomy can be generally stated as follows. State officials seeking solutions to urgent problems perceive academics as too theoretical, too slow to respond to problems, and difficult to communicate with. Academics perceive that state officials look for too simplistic answers to complex problems, are unwilling to develop true research applications, and are difficult to communicate with.

The irony of this standoff is that, quite often, the state officials are former students of the programs that they now disdain. This is not a problem without a solution. First, of course, is the need for communication and mutual respect. Second, each of the participants must acknowledge the attributes of the other. State officials are highly pressured to produce visible results in short time periods with limited resources. And they do seek help and innovative ideas. But there must be an attempt to understand their language and the scope of their problems. Academics are cerebral and introspective. They cannot always work in the same time frame or on the same agenda as a consultant, and they are independent. The latter is the key to the strength of academic research. State agencies must realize that just as they are constrained in how they deal with problems, universities are constrained in how they respond.

Universities have a primary obligation to educate their students. Utilization of students is paramount in research projects. In the short and long run this is,

consistently, the finest product of university research--a well-educated professional who will mature in his or her work.

Finally, faculty support can come from within the university. Many universities expect their faculty to show the outputs of a scholarly career--usually in the form of publications. Faculty seeking self-support often work on problems of their own interest. Such projects often become the seeds of more grandiose studies that might become funded by external agencies.

Research universities base their success on their graduate programs. At the heart of graduate programs is the ability to support students' activities during their graduate career. Such support requires substantial money. For example, a graduate student working on research might take 2 full years to attain a master's degree. The cost of supporting such a student might be:

Salary	$12,000/yr x 2 =	$24,000
Fringe benefits	5 percent	1,200
Tuition	$ 2,000/yr	4,000
Total		$29,200

Although universities have some funds to offset some of the student costs, they do not have adequate funds to support the number of students necessary to sustain a viable graduate program. Thus faculty is under pressure to obtain support for their research ideas, or to find research support for their program. This in turn forces the faculty to be more responsive to stated needs (rather than negotiate faculty-initiated ideas) and leads to some of the problems raised earlier, notably program context, program continuity, and uncertainty of research direction.

Absence of Support

It is difficult to sustain research and even in-depth academic programs in transportation in the absence of funded support. Students may be ambivalent about their career interests and drift to areas more promising in support. Often students (mistakenly) assume lack of research support implies lack of career opportunities; this has been occurring in graduate transportation programs. Without graduate students to pursue ideas and develop theories and hypotheses, faculty may also wander in their interests. Program dilution occurs. In addition, without faculty and students to contribute to the knowledge of transportation through the literature, programs lose their important dynamics.

Research is the glue that sustains a critical mass in transportation programs. Faculty share the excitement of solving problems with their colleagues; their students, often being classroom learners for 4 years, become real participants and real contributors to the solutions of the problems.

Research support must be considered an investment in

1. Education--the stimulus of and furthering of knowledge in a discipline. Research conducted at institutions is designed and devoted to the advancement of knowledge. Transportation agencies are not designed to educate or advance knowledge, their mission is to underwrite the provision of transportation services. The distinction between universities and transportation agencies must remain clear.

2. Long-term solution of problems. The accumulation of and advancement of knowledge at an institution can be called on, not only to respond to current critical problems, but also to reflect on and anticipate future problems. Further, if continuity of support is assured, these institutions can be called on in the future to deal with problems unforeseen now.

3. Future professionals. Transportation is related to nearly one-quarter of our gross national product (GNP). The organization, operation, and future of our transportation systems are complex, and large numbers of professionals will be needed to serve our transportation needs. Where are they to be educated and trained? Where will today's professionals get additional training? We must provide incentives for academic institutions to develop modern transportation programs. Without making this investment, the costs of our future transportation problems will be much greater than we can imagine.

FUTURE OF RESEARCH

University Approach

The methods of conducting research at a university--a professor or group of faculty working in concert with graduate and undergraduate students--is a continuing part of university life. The product of a university is the advancement of knowledge. Transportation research is not an exception. Transportation is an applied discipline. Housed primarily in schools of engineering, but increasingly housed in schools of management and planning, transportation is primarily professional.

Success for faculty in an academic institution is readily measured by attainment of tenure and promotion from rank to rank. The evaluation for promotions in research-oriented universities centers around scholarly output, the quality and quantity of published work, and the evaluation by peers of the overall content of the work.

Research is the method by which scholarly work is produced. As noted, transportation research is complex and applied. Although financial support for transportation research might provide the vehicle for the conduct of studies, it does not always lend itself to peer acceptance of scholarly research. There must be, at the university level, a filtering of projects so that those that lead to scholarly work can be accepted and those that are more geared to routine testing laboratories are not.

A review of current public agency research agendas shows that, at every level, transportation needs appear to be short range and applied. This does not mean that such research topics are without scholarly content. The opposite is true--a good researcher should, in addressing the problems that have been delineated, derive the more generic or causative components and report on them.

An example of successful approaches to such targeted problems is the measurement of displacement of embankments under stress during construction of highways. From a state highway department, the problem is perceived simply as one of developing a nomograph with soil type, level of stress, and height of embankment. University researchers, over the past 15 years have contributed not only new methods of layered-stress analysis and field instrumentation, based on a range of electronic theories, but also new methods of laboratory investigations and new theories that would help predict soil behavior under a range of conditions. Thus,

what begins as a seemingly mundane local problem results in major disciplinary advances that can be applied in a variety of other situations.

Current Trends

Because transportation as a discipline is so problem oriented, the focus of needs continually shifts. Universities, (continuity being one of their strong traits) cannot adapt as quickly to these shifts as needs dictate. University researchers have been spoiled over the past 20 years as transportation problems focused on the development and growth of our national transportation infrastructure. There was a long period to develop highway engineering programs and transportation planning programs, the latter often concerned with the establishment of long-term needs. Many of those needs have been met. The same problems of design and planning studied 10 years ago do not need to be studied today.

What needs have emerged from this 20 years of incredible growth? There will be the highway and transit needs of the next decade, and researchers will begin to adjust to the mix of technical skills to address them. These include all aspects of infrastructure renewal and developing new understandings of the place of public transit in our cities.

The first pressure on academic programs will come from the labor force. The demand for professionals to meet these evolving needs will result in program changes. Those universities with research programs directed to these issues will have the greatest national impact on curriculum changes as research results translate into required professional reading. We are beginning to see some of these changes occur. This evolution, of course, is a slow process. The amounts of federal funding for transportation programs available in the 1960s and 1970s will not be available, or will take different forms. Thus, more initiative rests in academic departments to sustain and underwrite the discipline as new priorities and modes of funding develop.

Future Needs

In an earlier section, I noted that universities had somewhat abdicated their roles in developing long-term transportation research agendas. It is essential that universities serve as more than reactors to the transportation research process. The link of computers to transportation (and the early notion of Dial-A-Bus) at MIT and the introduction of disaggregate demand models at Northwestern are excellent examples of universities taking the initiative and exerting long-term impact on the profession. Tomorrow's transportation needs are not entirely concerned with transit costs and pavement management. They include

- Further impacts of computers and communication technology on transportation,
- Advances in vehicle safety,
- Improved understanding of human factors in transportation,
- New generations of planning and forecasting models, and
- New vehicle energy sources.

Again, these are but examples on a long list. If we are not thinking about and studying these needs in our universities, we do a disservice to the profession. The university, in addition to having an analytic capability, has a historical obligation. Researchers study the past in their discipline in order to make advances; as such they have a perspective that is not duplicated elsewhere. This perspective must be used in delineating and studying the future.

We have built our highways and are using them. The research that helped in that task is now history, and, as such should be taught in history classes. It is time to look ahead to what we must build for the next generations.

Institutional Changes

In addition to program changes, which will occur because of changes in demand on the profession, organizational changes have taken place at universities. Many universities have formed interdepartmental transportation centers or institutions. Further, the federal government has designated centers to carry out specific tasks in transportation. UMTA has designated nine institutions to serve as transit training and research centers. In anticipation of future centers being funded, and as a result of further federal legislation, many groups of universities are forming consortia to combine the diverse talents and disciplines of those universities as well as provide extended opportunity for students to conduct research outside their own institution.

Although universities with existing programs in transportation have been finding new ways to accommodate or attract research, becoming much more entrepreneurial in their approaches, a major thrust has been initiated by the U.S. Department of Transportation to involve minority institutions (the largest segment of which are the historically black colleges and universities) in transportation research and training. With emphasis on proposal preparation, identification of research agendas, and major training workshops, a new peer group is finding its way into the research arena. Nonminority institutions have an obligation to ensure that this development is sustained and fruitful.

CONCLUSIONS AND RECOMMENDATIONS

We are currently involved in major changes in the development and use of our transportation systems in this country. Coincident with these changes are the research programs and academic programs needed to support our transportation systems during the next decades.

Research at universities is unique, must remain that way, and must be supported in its uniqueness. We must not forget that universities are not merely the symbols for the quest for knowledge; they are the workplaces in the quest for knowledge. Universities thrive on ideas, and not every idea is developed with the thought of a payoff.

Somewhere people must be allowed to try and fail, without risk. That is how a large number of paths are narrowed to a few. That is the source of debates about which productive inquiry is based. That is the source of the successes.

Conclusions

The inquiry into university based-transportation research has led to the following conclusions.

1. Transportation research is an integral part of academic programs at many universities and colleges. It is normally conducted by a team consisting of at least one faculty member and one student, often more of both, and often multidisciplinary.

2. Transportation research has a beneficial impact on academic programs. First, it provides new ideas and theories for use in a formal curriculum. Second, it provides both formal and informal training for graduate and undergraduate students in both the demands of their future profession as well as the methods of conducting rigorous inquiry.

3. Transportation research today is shifting from dealing with problems concerning the building and development of our infrastructure to problems of managing, operating, and extending the life of our infrastructure.

4. Transportation research at universities should be dealing with longer term needs of our population, including the impacts of rapidly changing demographics, a shifting economy, and the growing role of computers and communication in the workplace. It is not doing so now, although it is clear these influences will begin to have a major impact on our transportation systems within this decade.

5. Academic transportation research has been influenced by short-run, pragmatically stated national, state, and local needs. Academic research has been responsive to and creative concerning these articulated needs, and the profession has visible evidence of these successes. Understanding the costs and benefits of deregulation, utilizing new methods of planning analysis, and integrating microcomputers into all aspects of transportation are but a few of the many university success stories.

6. Academic research responds to its own reward structure. Promotion and tenure are often based on the quality and quantity of publications and the ability to obtain sponsored research. In recent years, however, the pressure to obtain sponsored research, per se, has begun to outweigh the academic merit of the research. Pressures to obtain research support, as such external support is dwindling, has led to some program disruption, some loss of students, and some loss of faculty (or shifting of faculty to more well-off institutions).

In one sense this restructuring is a healthy process. Institutions that cling to older models of transportation analysis might need some restructuring. In addition, the development of strong new programs to deal with evolving issues at institutions with relatively new transportation programs (many in the south and southwest, and some new programs at minority institutions) will lead to new program development by transference throughout the country.

7. What is lacking at traditionally strong transportation institutions is the development of new research programs that will address longer term, innovative transportation agendas. Such programs, because they are pathfinding, might need to be self supporting. In this era of pragmatically based research support, few external dollars are available for general exploration. The problems of developing such programs come, not from the lack of interest by faculty and students, but from the lack of encouragement by the institutions themselves. Transportation research must again capture the uniqueness of inquiry that our academic institutions have and can provide.

RECOMMENDATIONS

The following recommendations are made on the basis of the foregoing conclusions:

1. Academic transportation researchers need to be more introspective about the future of our transportation systems. We must gain some sense of the likely and fruitful directions in which our systems are evolving (or will be developed at) and conduct research and disseminate the results. Academic researchers must take a bolder hand in shaping transportation policy rather than reacting to it. This can be accomplished through a number of steps:

- University-sponsored conferences and workshops on future transportation needs.
- University allocations to support new-direction research. Such allocations might come from overhead generated from ongoing research programs.
- University research presence on boards and commissions.

2. Research boards (with strong academic research components) should be established to set transportation priorities, publish such priorities, and generate discussion on these priorities. Such boards do not need official imprimateur. They can arise from committees of TRB, or ASCE, or be ad-hoc committees structured by a group of faculty researchers and practitioners. Graduate students would serve on the boards or committees of the boards. They are the continuing links between academia and practice.

3. University researchers must become more vocal advocates of their profession. Their products--new ideas, well-trained professionals, and unbiased research studies have not been receiving the accolades they deserve. Perhaps the TRB Education Committee can take the lead in developing and disseminating a booklet on academically based university research.

Academically based transportation research has always demonstrated that it can be a good investment--a good investment to the sponsor, to the faculty, and to the students. By reemphasizing the university tradition of extending the base of our knowledge, we can be sure that the rewards to be reaped continuously from that investment will increase.