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ABSTRACT

A discussion of the problem of providing multidisciplinary education in transportation and a means for educators to communicate their approaches and experiences provided the purpose of the conference. Among the areas discussed were the comprehensiveness of transportation education, societal issues, systems aspects, transportation research, professional education in urban public transportation, content problems, societal contexts, and the shifting emphasis in engineering evaluation. (JMF)

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Multidisciplinary Education in Transportation

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Transportation Research Board 1974

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Multidisciplinary Education in Transportation

Proceedings of a conference conducted by the Highway Research Board September 7 and 8, 1973, at the University of Pennsylvania, Philadelphia, and cosponsored by the Transportation Studies Center, University of Pennsylvania, in cooperation with the 1907 Foundation

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Contents

Conference Summary and Conclusions

Anthony R. Tomazinis
University of Pennsylvania

This report includes the papers that were presented during the Conference on Multidisciplinary Education in Transportation that was sponsored by the Task Force on Multidisciplinary Education in Transportation Systems Planning of the Highway Research Board and by the Transportation Studies Center of the University of Pennsylvania. Those attending were primarily educators in some aspect of transportation from various parts of the country and from some European countries, other professionals in transportation, and pertinent state and federal governmental officials.

The purpose of the conference was to discuss the problem of providing multidisciplinary education in transportation and to provide a means for educators to communicate their approaches and experiences to one another.

The conference conclusions represent the product of the contributions of the speakers, the panelists, and the other participants. The intense interaction and discussion from meeting to meeting revealed both the extraordinary currency of the subject matter and its immediacy to the concerns of all those who teach in transportation.

SUMMARY OF PAPERS

Harris suggests that "a widely comprehensive training in transportation is the desirable goal of all transportation education." At the same time, he recognizes that "complete comprehensiveness is not achievable in the time span of ordinary education or perhaps even the ordinary lifetime." Given this limitation, he stresses "the desirability of comprehensive understanding [that] should be impressed on the student at the outset so as to provide a healthy antidote to overconfidence and narrow professionalization." He calls for a much more intensive educational effort so that a degree of comprehensiveness is always present as the various specializations within the field are being built up.

Manheim concludes that a new discipline and a new profession have emerged in the postwar years. The discipline has acquired theoretical underpinnings, methodological tools, and a vast area of involvement. Both the profession and the discipline are multimodal and carry distinct societal responsibility in meeting widely felt societal problems.

Wohl suggests specific tools and structure that educational efforts in transportation have already and should have in greater amount in the future. Systems analysis concepts and tools, he suggests, are of direct relevance to transportation, but he calls

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attention to the significance of the process of design or that of developing a synthesized solution that fits the problem. He points out some of the educational implications of this requirement.

Hobstetter presents the other side of the coin. Multidisciplinary education in transportation still must be carried out within established institutions and next to other similar and competing educational efforts. Educators in transportation will do well to remember, he suggests, that structural institutions have their rules of accountability or responsibility, their systems of evaluation and rewards, and their own human and institutional limitations. The ideal solution from one viewpoint turns out to be less than ideal from another. Goals are frequently conflicting and, in view of the usual budget limitations, priorities have to be established. Transportation educators should remember these realities and take them fully into account when they devise and recommend new setups to meet their needs.

This conflict between the university and the "field" is further discussed by Pignataro and Webber. Pignataro sees the "content problems" in the field as being extensive in nature and demanding in detail. Transportation is indeed multimodal today, closely woven into the fabric of society and its institutions. In addition, it is dynamic in its technology and impacts. Even its engineering aspects are multiple and inseparable from the economic aspects and the area impacts of transportation systems.

The discussion of content problems is further expanded by Webber. Without rejecting the significance of systems analysis and comprehensiveness in designing a transportation system, he suggests that the student should be taught to look at the larger implications of a proposed system. Major segments of a society and even whole cities and regions can be affected by a transportation system. This is an awesome responsibility and must be carried out well by transportation specialists.

Creighton suggests that professionals in the field be able to communicate, to handle extensive and imperfect data files, to devise specific and fitting solutions to actual problems, and to retain a measure of creative skepticism of their work and the circumstances within which they operate.

Although not given at the conference, the paper by Hall, Romualdi, and Roszner is included in this report in that it describes a program developed by the Transportation Research Institute for practicing professionals.

CONCLUSIONS

This conference was the first one held for the explicit purpose of discussing pertinent issues and of communicating ideas and solutions relevant to the problem faced by transportation educators. At the end of the 2-day conference, much discussion had occurred and participants had individually reached many conclusions. Five general conclusions deserve to be highlighted here because of their particular significance to the future of education in transportation.

1. A new profession and discipline are in existence today in the United States and some other parts of the world. The field of transportation was created by a de facto recognition of the dynamics and dynamism of the forces and concerns that are included in this field. Its multimodal nature and impacts seem to have fostered a whole corps of specialists, a vast variety of methods and techniques, a theoretical basis, and an activity extremely important within the technological society of the twentieth century and the mobile humanity that populates our globe.

2. The efforts in the field of transportation in general and in the field of education in transportation in particular have not reached any level of fruition that renders to the professionals and educators a feeling of comfort and satisfaction. The major strides in the last 2 decades are, of course, sources of pride for all those who made contributions, but they seem to have created almost as many problems as they attempted to solve.

3. The perplexity and the ambivalence that characterize the transportation field in the 1970s are manifest also in the educational efforts. In many respects, expectations

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have expanded; society expects beneficial effects both immediately and throughout the future. Transportation education has correspondingly been expanded and strengthened in the last 2 decades as many attempts were made to "catch up" and to "enlarge and enlighten" students and faculty. Transportation educators today are vastly better prepared than their colleagues were in the past but, nonetheless, have considerable doubts of what are or should be the desirable objectives and the advisable means. Agreement on goals and objectives is still not yet evident. Conflict and contradiction are frequent and real and extend to both the goals to be achieved and the means to be used.

4. The 2 branches of transportation—engineering and social sciences—are frequently at war with each other. Not even mutual respect for the role of each other is always apparent. The bridge that planners have attempted to build between the 2 disciplines has not yet been successful enough to close the gap. Engineers still reveal a belief that their discipline is the essential one in the entire field of transportation. Social scientists on the other hand frequently reveal a belief that engineering studies, plans, and projects are many times as wrong or detrimental to the welfare of the society as not. A note of contempt or disregard for the significance of the work of each other frequently escapes even in their guarded statements regarding transportation education. A major task is to improve communications between the 2 groups and establish the basis for mutual respect and appreciation. Only then can study and actions of multidisciplinary education in transportation become a reality.

5. Institutions of higher learning have not been persuaded that transportation should have any special advantage over any other field that has expressed a need for multidisciplinary education. Medicine, environment, city planning, energy, and other fields have also made demands for attention and special treatment. To all these fields, college administrators point out the need to respect already established and proven disciplines, to maintain university structure, to consider university budgets, and to recall the long-range and broadly conceived university objectives. Educators in transportation need to clarify their personal and collective relations with colleagues in related fields and to communicate the essence of these relations to administrators before they can expect action in their favor.

Comprehensiveness in Transportation Education

Britton Harris
University of Pennsylvania

The essential need for comprehensiveness in transportation education arises only indirectly out of the comprehensive nature of the problems of the field. The nature of these problems is a principal object of discussion in this paper. Like most professions, transportation management and transportation planning change rapidly under the impact of shifting technology, changing economic forces, and new patterns of demand. For this reason, it is not at all clear what positions, roles and responsibilities will engage graduates of educational programs in 5 to 10 years. A responsible attitude toward transportation education demands that we equip students not only to function in today's environment but also to adapt to major changes in the course of their productive professional lives. Although we can confidently predict that these changes will occur, we can only vaguely discern their content. Just as a prudent architect or city planner will produce designs that are to some extent adaptable, flexible, and generous to change (even at the cost of some present efficiency), so also the prudent educator should aim to place an adaptable structure of knowledge and equipment in the minds of students.

In current social organization and intellectual activity, many more or less general factors suggest that in many areas narrow specialization is drawing to a close. Russell L. Ackoff has powerfully argued that the intellectual advances of the Renaissance and the industrial revolution were reductionist and analytical and that they achieved their success by decomposing systems, but the current and future line of intellectual development will be ever more holistic and synthetic and will consider systems in their entirety. If one applies these ideas to concepts of professional preparation, it is clear that a comprehensive and broad-gauged training will be intellectually and operationally necessary for graduates to operate in the coming era. I subscribe to these ideas in principle, but I believe that their application to transportation and transportation education is more fruitful in the concrete sense, wherein we discuss directly the systems nature of transportation and the reasons why transportation planning cannot be treated from a reductionist point of view.

The transportation system per se possesses certain system characteristics, but only to a limited extent. Among these characteristic features, we may note some salient aspects. For any particular mode of transportation in an appropriately defined geographic area, the nodes, links, and equipment of the system function as a unified whole, and impacts on any particular element or group of elements are propagated through the system. At a slightly larger scale, different transportation facility systems compete with, complement, and generally interact with one another. Given the existence of facilities and the broad characteristics of demand for their use, the collection of different modes of transportation can indeed be considered a true system, and to a lesser extent particular modal facilities can usefully be treated as subsystems. This is the traditional engineering and academic approach to transportation systems, but it is largely inadequate to implement our evolving understanding of the role of transportation.

Let us therefore enumerate a few ways in which this traditional conception of transportation systems is not adequate. Most of these criticisms of the traditional view are based on the fact that open systems are difficult to study and analyze, and transportation is such an open system.

1. The provision of transportation facilities is dependent on a number of aspects of its social and economic environment, especially in urban metropolitan areas. On the one hand. streets are provided not only for transportation purposes but also for utility rights-of-way and pedestrian access. On the other hand, the construction of new transportation facilities in built-up areas is increasingly difficult.

2. Important substitutes for transportation exist. The most obvious of these is communication, and this will become a major force during the next 20 years because its relative costs will fall rapidly by comparison with transportation. In addition, there are less obvious substitutes for transportation in the organization and conduct of industrial, commercial, and familial activities. During the past 50 years, transportation has increased in importance by virtue of declining relative costs and elasticities of substitution, but this trend may be approaching an end.

3. A particular aspect of the openness of the transportation system lies in its relation with land use. On the one hand, transportation is a powerful influence on location and development, but on the other hand the location of demand is in itself an object of public policy and can no longer be taken as fixed or autonomously projectable. Therefore, transportation and land use cannot be planned independently of each other.

Some aspects of transportation are not directly dependent on its system characteristics, but have important influences on the comprehensiveness with which we must view the topic.

1. Transportation is principally an intermediate good and is only to a very limited extent an object of final consumption. As an intermediate, its relations with all other activities using transportation are important, and this includes nearly all human social and economic functions. To limit the comprehensiveness with which this problem is viewed, the relative importance of transportation must be scaled in relation to these different functions.

2. Transportation not only has intrinsic external impacts by virtue of its intermediate character but also has many other externalities in terms of its impact on the environment and its space-consuming and developmental aspects.

3. Transportation investments are typically lumpy, and in all probability important branches of the transportation industry enjoy decreasing costs.

Externalities, high investment thresholds, and decreasing costs are characteristics of transportation that make it well-suited to public intervention through policy-making, regulation, investment, or some combination of these activities, and we have of course seen the development of public activity in this field. The importance of such public interest and concern is emphasized by the high proportion of our gross national product—about 20 percent—which is produced in transportation and related fields. Given this basic public interest in transportation, we should note certain broad characteristics of public policy that influence the comprehensiveness required of transportation education.

From one point of view the principal influence in public policy-making on the comprehensiveness of transportation is an increased articulation of the goals and an increased sense of responsibility to a variety of interest groups. In the United States.

this new complexity of public policy-making is in part a response to political changes, in part a response to the expanded impacts of technology and population growth, and in part a result of increased affluence with its increased opportunities and heightened pressures on resources and the environment. Public policy-making in the United States must now contend with a great variety of objectives. Forty years ago relatively simplistic notions of efficiency embodied in cost-benefit studies were adequate for project evaluation. Now important considerations of equity to various income and ethnic groups have become a major consideration for reasons of both social justice and political expediency. These considerations of equity require a detailed and refined impact analysis with respect to those groups of the population affected by public policy. At the same time, issues having to do with the preservation of resources, the conservation of the environment, and the prevention of the degradation of the quality of life have become increasingly important. This raises a whole host of issues previously ignored. Finally, the joint consideration of these issues has brought an increasing realization of the complexity of the ways in which public policy decisions influence the development of society and the environment and finally exert their impacts on these matters of interest.

Partly because of the increasing number of objectives that must jointly be pursued by public policy and perhaps partly because of the increasing sophistication in government legislation, planning, and management, the number of instruments by which public policy can be influenced has experienced a corresponding growth in the same period. Even if the multiplicity of means of transportation planning and management had not increased, whatever instruments of transportation policy that are available would need to be evaluated and selected in conjunction with a greatly increased number of possible alternatives in other spheres of public policy. It should be clear from the foregoing discussion that these other public policy activities establish an important and inescapable environment for transportation development.

One other way of looking at the setting of the transportation problem may provide some useful insight into issues of comprehensiveness. This is to take up briefly some of the supply and demand aspects affecting the provision of transportation services.

The supply side of transportation services is of course a primary object of public policy in the context of a given technology and level of demand. One point that deserves emphasis is that the technology cannot in this dynamic era be considered fixed. The technology of air travel, for example, has moved from the DC-3 to the 747 in a period of 30 years. In the same period, the automobile system has been substantially changed by the construction of the Interstate Highway System, and ocean shipping has been influenced by containerization, supertankers, and the possibility of nuclear-powered vessels. Increasingly, the unified systems that are impacted by these technological changes are able to accommodate only a limited number of changes, which must be more or less universal. Wherever very large fixed investments must be made, and this is especially true of land transportation, diverse and incremental changes cannot be accommodated because they destroy intrasystem compatability. A difficult situation is, therefore, beginning to mature in which the pressures for technological innovation will increase while the demand for public control of new technologies will also increase, and the difficulties of assimilating new technologies in transportation may continue to grow. This evolving difficulty is, I believe, one of major interest to all transportation technologists. Although it is apparent that few will be directly involved in its solution, many will contribute indirectly, and all will have to be in a position to accommodate to major changes as they eventuate.

Not a great deal needs to be said with regard to transportation demand except to place it in a certain perspective as to the role of transportation education. Those in transportation planning and management circles have for many years thoroughly recognized that the estimation of demand and its projection into new situations are critically essential. They have also increasingly recognized that this estimation is not purely a problem in engineering or engineering economics but involves fairly deep considerations of social and economic behavior. On the other hand, the disciplines of sociology and economics have not been prepared to explore such problems at the level of detail ordinarily required in a variety of transportation studies. This problem has been intensified by the increasingly complex demands of public policy-making that I have just outlined.

Perhaps even more important is the beginning recognition that an important part of transportation planning may be the planning of the development of demand. In this case, instruments of planning and policy-making outside of the field of transportation—such as zoning, developmental controls, and the establishment of new towns—may increasingly be brought to bear on the solution of problems of transportation. This will escalate the requirements for sophistication, detail, and accuracy in demand estimation for transportation planning and management.

There is a final area, which I have so far implicitly ignored, in which a variety of skills ought to be imparted in a comprehensive manner in transportation education. Up to this point I have spoken as if certain analytical techniques applied at the system level might be adequate in transportation planning and management. It is clear, however, that a synthetic and creative activity, which is variously called problem-solving, planning, or design synthesis, is a necessary part of the professional competence of a mature transportation manager or planner. I do not propose in this paper to deal in any depth with the intrinsic nature of this synthetic activity, but for purposes of discussion I will assume that it has a certain broad relation with optimization and, consequently, with mathematical programming. In fact, it turns out that in most practical circumstances, the methods that can be used to solve problems and create viable and improved plans are not amenable to direct optimization. The heuristic methods that may be employed in planning derive in part from professional protocols or methods of work and in part from the formal structure of mathematical programming. It is doubtful that the protocols in their extreme idiosyncracy and richness can properly be taught, but there is no question that formal optimization methods are a proper subject of transportation training. It is to be hoped that, in the process of receiving this body of knowledge, students can be taught to respect its limitations as well as its powers.

We have now arrived at the following position. We see transportation as a major system consisting of a number of interacting subsystems, partly classified on the basis of mode and partly classified on the basis of geography. A proper understanding of the functioning and interaction of this system and its subsystems would be a major curricular program in itself. We see in addition, however, that other influences lead to a still more comprehensive view of the demands on the transportation professions. Transportation is embedded in a large-scale social and economic matrix having to do with the interaction between activities and their locational characteristics. At the same time, communication provides substantial competition to transportation, and the social and economic system seeks modes of adaptation that tend to minimize the demand for transportation.

Public policy is deeply involved in planning transportation systems and providing rules and regulations under which the private development and use of transportation systems take place. This public policy concern is related to efficiency, energy conservation, environmental protection, national distribution of population and economic activity, and equitable distribution of costs and benefits across different sectors of the population. This complex bundle of public policy objectives is pursued conjointly by transportation activities and a host of other private and public activities. In particular, the public sector has at its command an ever-increasing variety of public policy measures designed to influence the achievement of these diverse objectives. It is now becoming clear that the objectives of providing transportation services can also be influenced by measures completely outside of the transportation sphere. Finally, there is a growing public interest in the control of the development of technology so that society's long-term interests may be appropriately served and not disserved by this development.

Transportation planning and consequently transportation engineering have played an honorable and even a pioneering role in meeting many of these diverse demands. Transportation planning first devised large-scale socioeconomic surveys and their exploitation for facility planning purposes. This process also devised means of large-scale system representation on computers. It initiated locational modeling as embodied in many current land use modeling efforts. There are principally, in my view, only 2 major weaknesses in the field of transportation planning and its associated education. First, the use of economic and social concepts has been somewhat naive and not sufficiently broadly based. Second, the development of planning methods, building on the concepts of optimization of economics and operations research but extending them to practical situations of greater complexity, has been somewhat weak. These criticisms do not undermine a remarkable set of accomplishments, but they do tend to point toward directions in which these accomplishments might be improved.

On the basis of what has been said so far, it would appear that transportation education should deal comprehensively with a vast number of fields.

1. There should be the technology and system characteristics of transportation itself in all its aspects, with respect to all modes and all geographic scales and with respect to future as well as existing technology.
2. There should be a wide knowledge of the social sciences as they affect the behavior of households and firms, which make use of the transportation system. This knowledge must be realized in mathematical models.
3. There should be a broad and deep knowledge of the problems of public policy formation—both as to the objectives that are pursued and as to the instruments that are or may become available. This view of public policy is of course far broader than the study of regulatory economics in the various transportation industries.
4. The applications of many of the aspects of knowledge that we are discussing to transportation management and planning can only be accomplished with the use of large data bases and computer modeling. This implies that an adequate attack on transportation problems requires some basic understanding of computer systems and their use.
5. A systematic if not a mathematical approach to planning design and synthesis is required. This mathematical approach is quite distinct from the needs for mathematical modeling that are required to simulate the performance of transportation systems and the generation of demands on them. What is required here is an intelligent application of optimizing procedures at both the micro and the macro level. Such optimizing procedures will have some simulations embedded within them but go beyond the evaluation of plans in the direction of the generation of plans.

It must now be apparent that the requirements that have been outlined are in general excessive as a basis for transportation education. Few educators currently engaged in this enterprise could meet all the requirements, and it is doubtful that many graduates of current programs can be trained in a reasonable time to meet them either. We must, therefore, look for some criteria by which the degree of comprehensiveness of training in transportation can be limited while, at the same time, warn against areas in which limitation may be undesirable.

An obvious limitation could be achieved through specialization, and at least 2 specializations are available. One is by mode and the other is by geographic scale. I believe that a specialization by scale is far superior to one by mode. Metropolitan areas, national economies, and the world system have characteristically different transportation needs. Within any of these systems, however, the substitution and complementarity between modes of transportation are intense, and the joint movement of people and goods by related facilities is a major source both of economies and of conflicts. Although a concentration on geographic levels may thus be feasible. an exclusive concentration on a single mode or character of movement is quite out of place.

In dealing with social and economic phenomena in general, we cannot say that transportation has no influence in any selected area, but at least we can characterize activities by their sensitivity to transportation. Higher education and basic research on the one hand and problems of narcotic addiction and criminal justice on the other are relatively independent of transportation considerations per se. Contrariwise, the density of living arrangements, the location of retail trade and industry, and the national population distribution are all quite sensitive to transportation, and policies with respect to them may influence the direction of transportation development. Certain especially sensitive areas include the access of low-income and ethnically deprived populations to employment and to educational opportunities and the impact of location and of transportation itself on the environment. Transportation education does not need to transmit a full range of understanding of social and economic phenomena, but it must concentrate in a comprehensive way on those phenomena that are locationally important, that are influenced by the costs of interaction, and that generate large volumes of movement or gross environmental impacts.

At the technical level, in dealing with issues of survey techniques, statistics, computer data management, computer modeling, optimization, and so on, we must obviously pursue a selective approach. Any one of these fields can provide a lifetime specialization quite independently of its transportation content. Transportation students should however be well equipped in all of these fields to achieve 3 objectives:

1. Establish a basis for further acquisition of knowledge if this proves a professionally desirable step;
2. Deal intelligently with skilled professionals in the field and especially know how to avoid the imposition of bad advice; and
3. Understand the limitations of their own knowledge and the extent to which they are unable to wisely make major decisions and judgments.

This latter caution indeed applies to all of those fields in which the transportation student's knowledge will be less than complete.

My conclusion is that a widely comprehensive training in transportation is the desirable goal of all transportation education. At the same time, I am forced to recognize that complete comprehensiveness is not achievable in the time span of ordinary education or perhaps even in the ordinary lifetime. Given this limitation, I feel that the desirability of comprehensive understanding should be impressed on the student at the outset so as to provide a healthy antidote to overconfidence and narrow professionalization. To some extent, a sampler of a variety of fields must be provided to the transportation student, but this must be done in such a way that the weaknesses of limited knowledge are made apparent and the existence of much wider vistas is directly implied. Insofar as specialization will become necessary, a cognizance of the weaknesses as well as the strengths of this specialization should be an integral part of the education.

I think it is only fair to add that the development of methods and research tools by which comprehensive transportation planning and management can be achieved is a necessary foundation for sound interdisciplinary education. Although it is possible and even desirable for education to run somewhat ahead of professional practice, it is rare and almost impossible for it to run ahead of basic research and research practice. Any implied shortcomings of transportation education outlined here are therefore in part more generally shortcomings of the field itself.

Societal Issues and Transportation Education

Marvin L. Manheim
Massachusetts Institute of Technology

In the field of transportation today, a number of factors are evident: the emergence of a new profession; the emergence of new institutions; the emergence of new forces influencing transportation decisions; and the current backdrop of existing institutions.

We can indeed say that there is now a profession of transportation or, as some prefer to call it, transportation systems analysis. This profession has emerged during the last 10 years and is characterized by a number of features:

1. It is multimodal in perspective;
2. It is multidisciplinary, using the techniques and concepts of engineering, economics, systems analysis, operations research, management, law, political science, and the social sciences; and
3. It is multisectoral in that transportation system problems are treated from a variety of perspectives, including carriers, shippers, travelers, transportation operating agencies, state governments, local governments, federal governments, and international organizations.

The emergence of this new field is evidenced in several different ways.

1. There is now an intellectual coherence and unity to the field. The theory of transportation systems analysis has become clear, involving applications of economic concepts and using systems analysis tools. This theory has been used in a variety of applications, beginning with the urban transportation planning studies required in the United States by the Federal-Aid Highway Act of 1962; the Northeast Corridor project and other regional transportation studies; the Harvard-Brookings study of transportation policies in developing countries; and statewide, corridor, and new systems planning studies in North America and around the world.
2. The body of knowledge is now sufficiently large that no longer can one be a generalist in the field of transportation. The field is so broad that no single professional can comprehend and keep up with the current work in all aspects of transportation. Therefore, we now see the emergence of a variety of specialists such as demand experts, technology experts, evaluation experts, and network modelers.
3. A recognized professional community has developed. Within North America, the Transportation Research Board and the Transportation Research Forum are the

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leading professional organizations. Internationally, a variety of transportation journals specifically address the international professional community in transportation. Most recently, the First International Conference on Transportation Research was held in Belgium, and 140 papers were presented on various aspects of transportation research and policy.

In addition to the emergence of the profession, we should also note the emergence of new institutions oriented toward transportation. Multimodal transportation planning agencies and regional planning agencies with strong transportation capabilities have been established. And, in response to the Federal-Aid Highway Act of 1973, which includes significant changes in funding provisions for transit and highways, we are likely to see even more significant changes in the nature of the institutions in the transport field, especially in implementing agencies. In parallel with the above, a new set of forces have arisen to shape transportation decisions.

1. Citizen opposition to highways, airports, and other forms of transport as well. In response to this opposition, new legislation provides effective compensation to displaced families. Greater emphasis is given to citizen participation in the transportation planning and decision-making process, and a wide range of deep-seated and far-reaching institutional changes are in process.

2. Citizen concern for the incidence of effects. Which interests gain and which interests lose from various transportation decisions? The pressures of today are such that transportation professionals can no longer ignore these incidence issues even if they wanted to.

3. Greater public concern for the environment in all of its dimensions, especially as reflected in the National Environmental Policy Act of 1969 and in the Federal-Aid Highway Act of 1970. Section 136 (B). These pieces of legislation require procedural changes in transportation planning and decision-making to ensure more substantial consideration of adverse social, economic, and environmental effects throughout the course of transportation planning and decision-making.

4. A rising distrust of the professional, especially the transportation planner and engineer, and a crisis of confidence in the institutions, as well as the professions, involved in transportation planning and decision-making.

These forces have only recently emerged, and their power has only scarcely begun to be felt. As a consequence, transportation professionals, whether in the public or private sector, must be concerned with criteria encompassing a far wider diversity of considerations than efficiency, profit, and other narrowly defined criteria that historically were the basis for transportation decision-making. Even the very professional roles and attitudes of transportation professionals must change.

With the emergence of a new profession, new institutions, and a new set of forces to shape transportation decisions, we cannot but feel a sense of elation and excitement.

Yet, we feel also a sense of frustration. There are still large numbers of professionals whose education and on-the-job environments have not equipped them for these new conditions and in fact may hinder their abilities to adapt. For example, professionals such as civil engineers or economists each wear particular cultural blinders as a consequence of their education and training. The ability of most of the professionals involved in transportation to respond to the new forces has caused the crisis of confidence. Although new organizations with names such as "department of transportation" or "comprehensive planning agency" have been established, the job of bringing about attitudinal changes in a way that significantly changes operative behavior has just begun.

Even in the universities, we find great resistance to the changes required by this new field of transportation. The disciplinary structures and orientations of academic departments are significant barriers. Promotion and reward structures in many universities are still designed to reinforce individual egos rather than the ability to participate in a truly joint research or teaching effort, which may require significant changes in previous views. Although universities may pretend that they are capable of mounting mission-oriented interdisciplinary work, the production of a synthesis that is truly interdisciplinary and truly problem-related is often more the myth than the reality. The final report of a typical university interdisciplinary project is a compendium of separate chapters written by authors who do not even understand each other's jargon much less the substantive content behind the ideas.

Universities are static rather than dynamic institutions, resisting change rather than encouraging it. Severe limits on funds greatly constrain what they teach and the research they can do. Funds for basic research in transportation are almost nonexistent, and funds for significant curricular development efforts are likewise almost totally lacking. Therefore, it is difficult for universities to adopt new orientations and to make major curricular changes to respond to these new conditions.

Thus, a sense of elation comes from the excitement of what has been achieved in the short history of the transportation profession and the corresponding institutions. The frustration arises out of how far we have yet to go: how deep is the problem of institutional change, and how difficult the task of reeducation of present professionals to a new perspective. Some may say we are too impatient and unwilling to wait a generation of 15 years (or more) until graduates reach positions of middle management where they can in fact operate with the new transportation perspectives. This impatience reflects, however, the conviction that the challenge posed by emerging new forces is too important to wait.

One way of summarizing the above discussion is to identify the basic substantive principles that must be addressed in incorporating consideration of societal issues into transportation education.

1. Transportation affects society. Any change in the transportation system of a region affects human behavior. In the short run, behavior of travelers is affected. In the long run, human behavior is changed in a variety of ways in that the location and structure of social and economic activities may be significantly influenced. Because of the significant effects of transportation decisions on human behavior in the short run and the long run, transportation must be seen explicitly as only one set of instruments within a broader set of more comprehensive planning and public decision-making options.

2. The effects of transportation must be viewed in terms of the differential incidence of gains and losses: which interests benefit and which interests lose from each course of action. This is both a moral imperative and a politically pragmatic one. As a matter of political reality, neither transportation analysts nor decision-makers can ignore any longer the issues of which groups benefit and which groups lose.

3. Transportation decisions are influenced by what happens in society in that all of the interests that may potentially gain or lose from a transportation decision on a particular course of action will play some role in influencing the decision that is taken. From a practical point of view, this means that the transportation analyst cannot assume that he or she can operate in a rational, objective manner completely aloof from the political process and deliver recommendations from a supposedly objective and value-free perspective. Such a perspective does not and cannot exist: and if the analyst pretends to be value free, he or she will reflect a set of biases that is perhaps worse than an explicit value bias. In other words, transportation professionals must realize that they are inevitably actors in the political process and cannot escape this. They must, therefore, define their professional responsibilities accordingly.

4. As a consequence, professionals in transportation have a role that is changed significantly from that which was visualized in the past. The professional can no longer hide behind a shield of supposed expertise. Rather they must be on the firing line of the political process, interacting with a wide variety of different interest groups, taking responsibility for what they analyze and how they analyze it, and exposing their professional judgments and value biases (implicit or explicit) to scrutiny, hostility, and criticism.

5. Change is required in our institutions to allow the transportation professional to take on this new role.

The above observations imply a general need for a new kind of professional not just

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in transportation but in all of society. The new professional must have expertise in 3 major areas: technology; interactions between technology and society; and role perception and capabilities.

By technology, we mean an understanding of the performance and characteristics of a particular set of physical systems. For example, in transportation, what is required is a mastery in a fundamental way of behavior of transportation systems and of the methodological techniques useful in analyzing those systems.

By interactions of technology and society, we mean the understanding of the way transportation can influence the structure and functioning of social, economic, and political systems and the way these systems in turn influence the decisions that can and will be taken about transportation. In the short run, transportation influences the activity system in terms of changes in travel behavior; this is the problem of forecasting the demand for various transportation systems and services. In the long run, transportation influences the activity system; this is the problem of predicting land use and other long-term effects of transportation on society. In both the short run and the long run, there are elements of understanding cause-and-effect relations—what transportation system changes cause what changes in the activity system—and of understanding the institutions that are affected by, and that can affect, transportation decisions.

To master the technology and the interactions between the technology and society, transportation system professionals must acquire substantive knowledge about cause-and-effect relations within transportation and between transportation and society. They must also develop skills with a wide variety of methodologies (often referred to as "systems" techniques) including statistics, social science research methods, computers, economic concepts, and visual design capabilities.

Since 1966, the transportation systems analysis educational program at M. I. T. has been based on the premise that the transportation professional must have a deep understanding not only of the technology of transportation but also of the interactions between transportation and society. The program is also based on the concept that each student should master the substantive material—the methodological material, the systems techniques, and some aspect of the environment of transportation. The transportation and systems analysis requirements have been met by a mixture of core courses in multimodal transportation system analysis and systems techniques and of a wide variety of electives in various areas of transportation and systems analysis. The requirement for competence in some aspect of the environment of transportation has been met by requiring courses in areas such as urban politics, social policy, economics, management, and law. These concepts have been applied to doctoral programs as well as master's and undergraduate programs.

However, we have only recently begun to realize the need for material in the area of role perception and capabilities. This recognition has come about because of field work with state highway departments and the U.S. Department of Transportation and because of the frustration in the face of elation with which we closed the discussion in the first section of this paper. By role perception and capabilities, we mean the development of an individual's sense of himself or herself as a person and as a professional. This includes

1. A sense of history and destiny through understanding the changing world of humanity and the changing role of institutions in that world as reflected in a deep knowledge of history and humanity;
2. Understanding of the processes of innovation and change and of the means of change, achieved through historical studies of changes that have occurred, through evaluation of particular changes from various value perspectives, and through appraisal of the strategies and tactics by means of which various changes have occurred or could occur;
3. A sense of values in the senses of "ethics", of understanding how value conflicts arise, and of a deep-felt humility about the individual professional's role and capabilities in society (out of such a sense of values can come the basis for an individual's formulating a personal value position, especially with respect to the objectives of change);

4. A variety of personal skills, including understanding strategies of change in complex institutional environments, understanding the tactics of change, and developing management skills and skills required to operate effectively as a member of a team in an interdisciplinary context; and

5. A personal philosophy and articulation of personal objectives in the sense of arriving at an individual position as to one's personal and professional role in society.

Essentially what this means is that, in addition to an understanding of technology and of the interactions between technology and society, transportation professionals need strong convictions about their roles as individuals and as agents of change in society. These convictions must be rooted not only in a sense of history and an understanding of the historical processes of change but also in a personal value position—a clear articulation of personal professional goals in society.

This general philosophy can be brought into focus by a description of how this can be reflected operationally in the actual work of a transportation system professional. The analysis of the transportation system analyst should be structured in a way that is relevant to the political context in which he or she operates. This includes

1. Recognition of the incidence of gains and losses;
2. Recognition of the value biases that can be hidden in modeling assumptions or interpretations of data;
3. A concern for bringing out trade-offs and for clarifying objectives through analysis in a politically relevant way; and
4. Conscious and deliberate structuring of strategy of analysis to use effectively scarce resources of computer time, dollars, and skilled workers to accomplish an analysis that can influence the individuals and institutions that have the capabilities to make decisions and that can thus bring about change in the real world.

Perhaps one way of summarizing this concern is as follows: We as transportation professionals are in fact "change agents" in society. We need to educate ourselves to operate effectively in that role.

Thus, when we consider the topic of societal issues in transportation education we conclude that a new educational concept is necessary. This concept, although perhaps not so new in other professions such as business or social work, is new in engineering and in transportation particularly. The concept is that transportation professionals must understand their technology; the interactions between their technology and society; and their professional roles and capabilities as change agents. The real challenge is to work out precisely what this concept implies in terms of specific curricula. This concept should apply at each educational program level:

1. The professional or engineer's degree, which requires 6 to 7 years of total professional training with some kind of practical training in an internship (2 to 3 years beyond the bachelor's degree).
2. The preprofessional or bachelor's degree.
3. Certificate programs of 1 to 2 years and short-course programs of 1 week to 3 months for practicing professionals.

The development of such programs is not at all easy. There are a number of problem areas:

1. Resources. Significant resources will be required to develop the substantive material to put flesh on the bones of this program.
2. Relations with other disciplines. In developing such a program, we need to draw on the insight and experience of applied social scientists in fields such as organizational behavior, cultural anthropology, and sociology. However, pressures on individuals in these fields are toward a disciplinary orientation to their own professional peer groups, and present university structures do not effectively reward work of such professionals on a team basis to develop transportation or other similar curricula. Furthermore,

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the problem of building communications at a level of operative understanding is extremely difficult and takes an investment of several years on the parts of all concerned.

3. Research base. To teach the kind of things we want to teach, we need to do research in these areas so that we are at the frontiers of knowledge and are able to communicate that excitement and insight in the classroom. At M. I. T. we have been very fortunate in recent years to be able to do some applied research in this area, but the funding and nature of that work have been such that we have only made uncertain approaches like children groping in the dark rather than acquired the knowledge that we really should have mastered in order to do the research we are doing.

4. Faculty roles and life-styles. We can no longer operate as self-centered professionals, striving to reinforce our own egos by producing our own identifiable pieces of work in a relatively abstruse, narrow area. Rather, to be effective as teachers in this new kind of curriculum, we ourselves have to be far more willing to work closely with others.

To summarize, if we look at the issues of societal concerns as they impact on transportation education today, we must conclude that transportation is an important agent of change. Therefore, our highest priority must be to develop a deep understanding, in ourselves and in our students, of our professional roles and capabilities as agents of change in society.

Systems Aspects in Education for Transportation

Martin Wohl
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What do we mean by systems analysis or systems engineering as applied to transportation? What are its requirements, and how do we mount such an effort in an educational institution?

By systems analysis or systems engineering we mean that the system—as opposed to its individual parts—is to be analyzed or engineered, that interactions among the parts and subsystems are to be considered in the overall design, and that the best overall design is to be sought. In a real sense, then, the fundamental task of the systems analyst or engineer is to synthesize rather than to analyze. Although many analysts and engineers clearly understand this notion, they invariably emphasize analysis rather than synthesis.

There are, of course, valid reasons for this emphasis. For one, our understanding is considerably better of analysis than of synthesis. We also have more experience in teaching analysis than synthesis. In addition, it is difficult to teach synthesis within the current framework of educational institutions. In fact, even to teach the basic scientific tools that are requisite to synthesis is no small undertaking in the present university environment. Why? Because engineering schools have traditionally and principally regarded themselves as technological creatures, as purveyors of a knowledge of physical science and of technological skills, and as analyzers. The art and science of design or engineering are taught more as a handbook skill rather than as an optimization problem and as one requiring massive synthesizing talents.

To teach linear programming, for example, is not necessarily to teach optimization. Nor will a massive dose of operations research, linear and dynamic programming, statistics, higher mathematics and data processing—whether or not supplemented by a smattering of economics and political science—necessarily equip students with synthesizing capability. Students should desirably have all these and other scientific skills, ones that fall within both the physical and the social sciences. But they also must be able to understand how to usefully and efficiently apply these scientific skills and this analysis base to particular design or system problems.

Undoubtedly, some will argue that a number of schools already are offering substantial educational programs in transportation systems analysis or engineering. Unquestionably we are now providing transportation students with better preparation for engineering, design, and planning, but I do not think that either undergraduate or graduate programs teach systems analysis or systems engineering in the sense I mentioned earlier. Rather, our present programs can be better described by the term "engineering science." Contrarily, some understanding of the system problem is being gained—by teacher and student alike—from courses in economics and from team study and projects. But efforts in this regard are few.

Let me be more specific about the requirements for transportation systems analysis or engineering. An educational program in transportation must provide knowledge in 3 distinct areas. First, knowledge must be acquired in pertinent physical and social sciences. Considerable emphasis must be placed on developing the analytical skills important to systems analysis. Second, a solid understanding of the technological system, its components, and operations, both present and potential, must be provided. Third, the process of design (or engineering or synthesizing) must be understood. Clearly, the third area can be successful only if the knowledge in the other two is complete.

The third area is, of course, the key one for this discussion. One can have obtained all the scientific knowledge and analytical skills and know all there is to know about transportation hardware and still not know how to design and how to obtain a better solution. This third area is, in essence, systems analysis. The crucial elements or steps of the process of conducting transportation systems analysis are (a) determine the alternative designs and operations (to include various regulatory and pricing options) that are most worthy of comprehensive analysis, (b) predict the consequences stemming from the alternative actions, (c) evaluate the consequences enumerated in step b, and (d) determine, on the basis of the information obtained in steps b and c, which action or alternative is better or best.

To be successful in teaching systems analysis will require a faculty that is multidisciplinary, has a range of technological, methodological, and scientific skills, and can effectively synthesize this knowledge and these skills. In addition, an appropriate setting must be established for conducting well-integrated courses in transportation systems analysis. Although it is difficult to be precise about what defines an appropriate setting, the following are some suggestions.

1. Transportation systems analysis probably should be taught in 2 stages: the first of a more descriptive nature at the outset of a transportation program and the second of a more rigorous and analytical nature toward the end of a program. The purpose of the former is to provide an understanding of what transportation system planning is and consists of and what one needs to know to tackle a large-scale system problem. The purpose of the second stage is to teach the application of the skills, tools, and knowledge and to carry out a comprehensive systems analysis project.

2. Transportation systems analysis courses, seminars, or projects should be conducted by faculty members from a number of disciplines who actively, jointly, and simultaneously attend and participate. This is to recognize that no one faculty member can know everything or even enough about everything and to encourage if not require more interaction among faculty and students alike. Also, it is to state in unequivocal terms that we must start teaching students synthesis rather than let them learn it later or not at all.

A final aspect about teaching systems analysis in transportation regards whether it can be successfully taught within the present institutional setup. For some years, we have offered programs dealing with railroads, highways, airports, and now transportation. In early years, the offerings were principally railroad or highway engineering, whereas now they extend to highway or transportation planning, transportation economics, or even transportation systems planning. But despite the broadening in course offerings, or even that in the faculty's training and interest, we do not have an appropriate home or institutional setting for either faculty or, in turn, students.

Stated rather bluntly, the disciplinary structure, together with its procedures and yardsticks for promotion and tenure, usually forces a transportation system analysis program to be housed within an engineering department or an economics department or within some other disciplinary unit. An economist, for example, is usually not at home or welcome and does not have the necessary credentials for full-time and permanent

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association within an engineering department, and vice versa. Thus, the ties must necessarily be loose and tenuous. What is needed is an organization unit in which transportation systems analysis or planning is the key issue and in which many disciplines can be jointly and permanently housed. Until this can be achieved I remain dubious about our ability to mount solid and comprehensive programs of the sort we are interested in.

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Mission-Oriented Research and Education

John N. Hobstetter
University of Pennsylvania

This author brings an assuredly long and somewhat varied background to bear on his assigned subject. Although I am an engineer and applied scientist, my path has brought me to several rather different perspectives of the problems of research and education and particularly of those that cross the traditional disciplinary structures of the academy. Since I have had no experience in the field of transportation, forgive a little personal history that may help account for my having been asked to participate in this conference.

My professional career began at Harvard during World War II, when I headed up a research project that was indeed "mission" oriented. We were part of the NDRC effort to find a way to make aircraft machine gun barrels last for more than half a mission! The effort succeeded, and B29s were able to return to Guam from Okinawa with their guns still firing. At the end of the war I got a doctoral thesis from that work. It concerned the behavior and erosion of materials under extreme physical, chemical, and mechanical stresses. From this experience I learned that mission-oriented research can contribute to basic, disciplinary knowledge. However, I feel that this is not always so and that in the more typical case the flow of information is largely in the other direction.

I later moved to the Bell Telephone Laboratories at Murray Hill. The laboratories took pride in emulating the universities and required no particular Bell System-oriented work of its basic researchers. We were free to follow our own research leads. But I soon noticed that my colleagues whose work did lead to patentable developments relevant to Bell System needs enjoyed certain economic advantages over those of us whose work did not! From this I learned the role of incentives in stimulating mission-oriented work.

Still later I came to the University of Pennsylvania to take up again my first and only professional love—the academic life. I joined the renascent metallurgy department, but in no way did I move comfortably into what had been the heart of that discipline. I had been at Bell during the great days of the research explosion in semiconductors, and my work there had centered around those (then) exotic materials. I continued that pursuit at the university. I may note here for the uninitiated that research in semiconductors tended to be part chemistry, part metallurgy, part physics. Thus I was, if not a mission-oriented researcher, at least a confirmed interdisciplinarian.

This stance took ready root at the university. My colleagues were interested in

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interdisciplinary materials science, particularly when the prospect of major federal funding for it appeared. Incentives again! The university prepared a proposal to build and operate a major interdisciplinary research laboratory for the materials sciences. The plan was well conceived and the first choice when the large ARPA support for this field became available in 1960. We built a physical plant, we stocked it with unparalleled central research facilities for interdisciplinary use, and we obtained forward-funded block grants to stimulate research and graduate training. I served as director of the laboratory for its first 7 years.

We certainly had the right environment and handsome economic incentives to use. Were we successful in stimulating interdisciplinary research and training? In some ways abundantly yes; in others disappointingly no. Faculty and students got to know each other and to respect each other's work. With our incentives we were able to induce departments to bring in new faculty to exploit the emerging possibilities lying in the heart of the laboratory's mission. Among the fruits of this are our world-famous Solid-State Physics Group and Department of Metallurgy and Materials Science. But funding alternatives for the faculty were numerous, and the tradition of private entrepreneurship remained strong. Our new faculty did not happily join in teams to attack their problems with new interdisciplinary perspectives. They tended by and large to work as individuals in an essentially disciplinary way. Only more recently, with strong mutual confidence gained and with funding alternatives now fewer, has the faculty rethought its situation and started to regroup its work around the major problems of materials science. From this I learned that faculty members are and probably always will be individuals first. More tentatively I might also conclude that a little stringency is not necessarily without rewards.

In 1967 I joined the central administration as the vice provost for research. This post was supposed to broaden the reach of my gaze. The sight was breathtaking, and I rushed into the scene with all the enthusiasm of a puppy. And I fell flat on my face. I attempted to put together in the urban-regional research a center somewhat like the laboratory I had just left. The center was intended to provide focus and synergistic integration to the university's far-flung but fragmented research efforts in this area. Faculty members with whom I discussed this project were enthusiastic. However, without facilities and incentives, the center had to rely solely on good will and the power of the jawbone. I had learned my lessons about incentives, but I did not apply them. The first meeting of the faculty of the center fell apart in discord, and the center never really got off the ground. What I learned from this experience about incentives was not something new. Rather it fell in the category of what psychologists who train rats in mazes call "reinforcement."

Now, as associate provost for academic planning, the problems of new modes of research and education are an immediate concern for me. It is from that vantage point that I would like to present for consideration and discussion what I want to subtitle "A View from College Hall."

Let me begin by denouncing the title in which this presentation is being made: "Mission-Oriented Research and Education." (In the first place I notice the acronym is MORE. As a budget officer that intimidates me!) Furthermore, I do believe that mission-oriented research, in the usual sense, should not be done in universities. It is not only a question of our being poorly structured for such endeavors or that our decentralized style and the requirements of academic freedom make them difficult. Rather, I would say that universities do not exist and indeed should not exist as utilities to be used by other outside agencies in the achievement of outside utilitarian missions. Universities have missions of their own, which are defined quite differently. In this second definition—the self-defined missions of the university—everything we do is mission-oriented, but I fear that is not the sense intended.

Instead, the planners of this conference had something quite different in mind. They are asking questions about how the university structures knowledge, structures research, and structures education. They are asking us to consider that, in addition to the conventional disciplinary structure of our activities, there may be an important new dimension in which the disciplines can regroup themselves around complex problems and synergistically generate new knowledge and methodologies that illuminate those problems and reveal better optimizations through which to address them. I believe, profoundly, that universities must find better means to encourage such problem-oriented thinking, and I see little evidence that we are succeeding outside the confines of certain professional schools.

What do we see when we look at a university from college hall? We see our schools and their faculties and students to be sure, but most conspicuously we see that our schools are departmentalized. The academic department is mainly an American invention that has succeeded beyond all expectation and has been imitated everywhere. In the long history of higher education it is a recent development. Almost all departments are less than a century old and many are less than half that age.

We see the departments as keepers of the academic disciplines—a function that makes them a principal glory of higher education. Each helps define the coherent body knowledge that is the content of its discipline; each helps to shape the rigorous methodologies by which new knowledge can be gained; through peer review each helps to certify contributions to knowledge whenever made; each evaluates the credentials of would-be scholars and therefore controls entry to scholarly life.

Universities depend on these legitimizing functions of departments and would be quite helpless if they were not performed. It is sometimes said that departments are self-selecting and self-serving in the exercise of these functions. There is truth in this, but how could it be otherwise? A living discipline explores the frontiers of knowledge, and it is likely that only those working those frontiers can truly see where advances are occurring and who is making them. If this self-perception and self-evaluation encourages a kind of orthodoxy on the one hand, it tends to ensure quality on the other, and quality is a precious thing.

The danger is that not all disciplines we have are living disciplines. Some are moribund; some few seem to enjoy a zombi-like existence that the system tends to protect—one dead hand washing another. Universities have not found adequate means of recognizing and dealing with the natural process of disciplinary demise. We must do so. On balance, however, any detached observer of the academic scene must conclude that departments and the disciplines they keep are indispensable and are a conspicuously successful invention.

Because they are the chief budgetary units of the university, disciplinary departments have one attribute that is particularly relevant to my topic. They control incentives and rewards for their faculties. Because a living discipline constantly enlarges the frontiers of knowledge, there is no lack of important topics on which to work. Topics lying in the heart of the discipline are the ones recognized as most important by departmental peers. Success in pursuing these topics can be expected to induce such rewards as salary increases, promotion, tenure, professional recognition, and prestige. Researchers who attempt to work in a wider problem orientation, along with colleagues from other disciplines, often find their work regarded as peripheral by their departments. Even if their work is seen as good, they may be told that equal effort would have earned more brownie points at home. Often their departments may feel quite incapable of evaluating their performances. If so, then there are usually no alternative administrative structures to carry out that important task and provide rewards for good performance. This is the very heart of our problem.

There is a pressing need for universities to mobilize their disciplinary expertise around the critical problems of society in these times of rapid change. Transportation, energy production, energy management, delivery of social services, setting of social priorities, decay of cities, suburban sprawl, worsening environment—the list of problems seems endless. If we do not address these things, we shall run grave risks that the society that supports us will find us increasingly irrelevant to its needs. Experience also teaches that we shall not be able to address these things unless we are ingenious enough to devise new structures to carry out for problem-oriented activities the same kind of legitimizing functions the departments carry out for their disciplines. Universities must depend on those closest to the action to tell us of new knowledge synthesized, of key contributions, of deserved rewards, of quality perceived, of successful curricula. Administrations cannot do these things alone. Conventional departments seem unable to help. New forms are needed.

Attempts to construct alternative structures must take account of special attributes of problem-oriented research and education that are not shared by conventional disciplinary departments. Our disciplines may not actually be so eternal as they are sometimes thought to be, but surely their effective life is very long. Their very stability makes wholly appropriate such things as academic tenure, long-term endowments, and capital investments in a specialized plant.

Problems, on the other hand, are meant to be solved. Problem-oriented research and education may be a valid activity during a relatively short term. Success, instead of leading to its growth, may lead instead toward lesser need. Success should probably be followed by a regrouping of the expertise of its researchers and trainees around other problems. Only basic knowledge and techniques persist. Our new structures, then, must have a flexibility, a plasticity, and a "terminatability" unknown elsewhere. Tenure surely cannot be handled conventionally. Instead of endowments we may need "annuities" whose principals can be consumed within a decade. Any new physical plant should be flexible enough to meet all kinds of needs.

At the University of Pennsylvania we have begun to experiment with new structures of this type. To stand in for the department we have recreated several groups that go by the unpleasantly neutral name of "academic unit." A unit has many of the prerogatives of a department. but quite explicitly it is subject to review every 5 years to see whether it shall continue or be terminated. A unit may accept students, set curricula, organize research projects. and raise gift and grant funds. It has a budget, can hire staff, and can initiate proposals for faculty appointments and promotions, although under particular constraints. It seeks to place its appointments in the first instance in the regular departments, seeking for these posts well-qualified disciplinarians who wish to work for a time in the program of the unit. Nondepartmental appointees of the unit are not appointed for terms longer than the approved life of the unit. This last constraint may not be ideal, but on balance we believe the whole concept is a valuable step forward.

When a unit is encompassed within an existing school, no other new structures seem necessary. The Unit for Multi-National Enterprises in the Wharton School is a case in point. But many conceivable units would cross school lines in complex ways. For example, if we were to set up a unit for transportation studies, major participants would come from the Wharton School and the Engineering, Law and Graduate School of Fine Arts. None of these schools seems likely to be a comfortable home for such a unit. Energy management, urban studies, and the like are other conceivable new units with a similar interschool character. For all these some new structure seems needed to stand in for the faculty of a school. For a faculty also has important legitimizing functions of its own. Among other things it provides comparative assessments of the quality of the research and educational programs of its departments, provides a framework for interaction and mutual enhancement, and helps assess faculty credentials.

I have proposed that we consider setting up what I have called "faculty councils" to fulfill this role. A council consisting of the faculty members who are active in all of the units we might set up in the urban-regional-environmental-energy-planning area would have a useful community of interest, shared values, and similar discipline origins. Such a council would be well-equipped to serve the university in assessing, controlling, and legitimizing the programs of its units. Membership in the council could vary as would that of the units, and its life could be similarly finite.

No doubt other alternative structures are possible, perhaps some far superior to what I have outlined here. Of one thing only I am sure. If problem-oriented research and education are to thrive alongside our disciplinary programs, then new legitimizing structures are essential.

Transportation Research in Universities

Thomas D. Larson
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Before university research is discussed, the relation between research and educational programs in universities should be established so that we have this larger context before us. To do this rather simplistically, one can observe that essential elements of educational programs are students and teachers. Research supports students directly through some form of graduate assistantship and professors both directly through salary maintenance and indirectly by providing students in the classes they teach. Beyond this, however, there are other benefits to the university such as faculty improvement, introduction of students to the real problems, and enhanced faculty-student interaction.

One should not, however, become complacent with any current view of this relation. From an objective, overall effectiveness perspective, the tie between research and educational programs can and is being questioned. The following are some of the issues.

1. Does the tendency of faculties to reproduce themselves in their graduate students make this training mode inappropriate in a time of rapid change?
2. Are there more cost-effective ways to do both advance training and research, e.g., forgiveable loans and grants to students who can choose the most responsive institutions and nonprofit research organizations?

In launching its university research program, the U.S. Department of Transportation gave several reasons why high-level transportation research was important.

1. The transportation industry is large, approximately 20 percent of the gross national product.
2. The industry is technology-intensive, and U.S. technological leadership is lagging.
3. Problems are severe and touch all of society.

The conclusion was that universities should be involved because they are needed!

What then is the current level of university involvement with research in this critical area both in absolute and relative terms? In 1972, total interaction of the U.S. Department of Transportation with universities was given as only $10 million per year (see Fig. 1), which was concentrated at 10 institutions. This was only some 5 percent of

Figure 1. U.S. Department of Transportation obligations for research at universities.

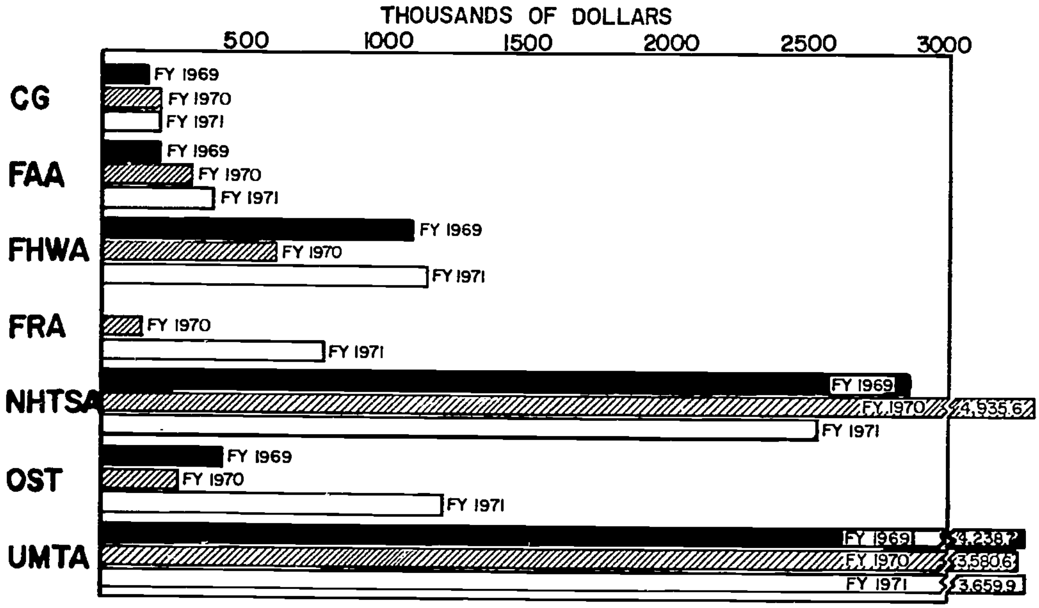
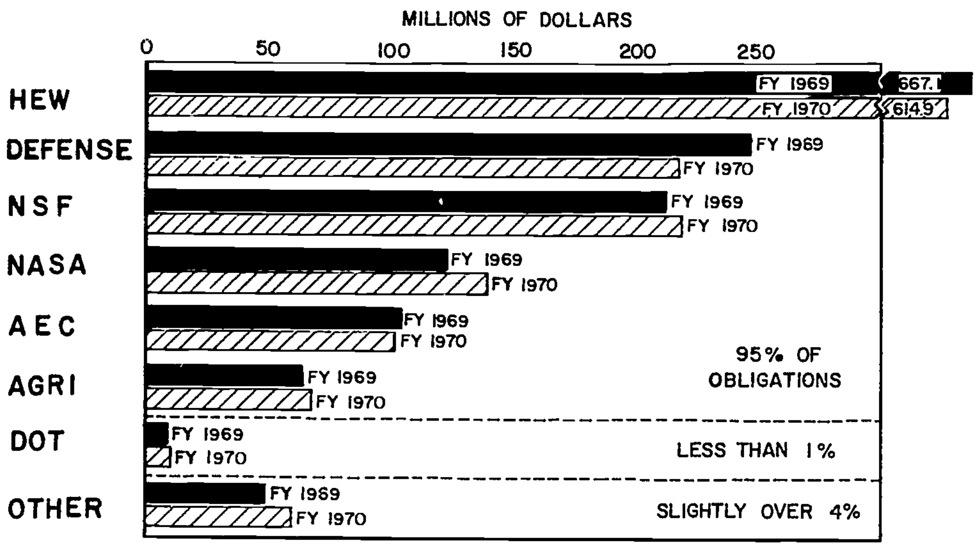


Figure 2. Federal obligations for research at universities.



the total research and development effort of the department. Furthermore, the total transportation department funding accounted for only 1 percent of federal research and development support to universities (Fig. 2). Several conclusions might be drawn from these data. One is that the allocation of 1 percent of federal research money to universities for research on a function that represents almost 20 percent of the GNP is wholly inadequate, or alternately that transportation research is largely inappropriate to universities.

CURRENT PROGRAMS

Various programs provide support for university transportation research. Some are old, are well-known to almost everyone in the university community, and have well-established philosophies, operational guidelines, and clientele. Others are newer, some of which are still in a shakedown period. However, old programs are changing and new ones are increasingly directed to changing emphases in transportation. Therefore, a review of current programs is chiefly of value in providing a context for discussion. I will now discuss briefly the history, philosophy, impact, and current status of several well-known federal programs.

Research Applied to National Needs Program

The Research Applied to National Needs (RANN) Program of the National Science Foundation began in 1971. It was developed through an extensive planning, coordination, and evaluation process that focused special attention on national needs and capabilities to meet them as viewed by leaders of the scientific and technical communities, universities, industries, other federal agencies, and state and local governments.

The purpose of the RANN program is to focus scientific and technical research on societal problems of national importance with the objective of contributing to their practical solution. RANN supports problem-focused research in areas that hold promise of technical, environmental, or socioeconomic payoff through the application of scientific knowledge derived from basic research.

Among the criteria used to decide whether a specific problem should be addressed by RANN are the following: the importance of the problem, the payoff potential in relation to the anticipated costs, and the readiness of scientific and technical people to deal with the problem.

Several of the RANN program elements relate to transportation: social systems and human resources, with initial problem areas including municipal systems and evaluation methodologies for social programs, and advanced technology application, with initial problem areas including urban technology and energy resources research and analysis. As a more specific example, a solicitation by NSF Division of Social Systems and Human Resources had as one topic "Decision-Related Research in the Field of Local Government Management." The specific problem was that of developing measures of the effectiveness of local service, including housing, public health, local employment, recreation, and transportation.

Since RANN is a recently developed program, it is not possible to assess its impact. However, it has a significant and increasing support level—$53.8 million or 9 percent of NSF funding in 1972. The impact of this program may well turn on how the transportation system planners relate their research to the larger societal context. At an even more abstract level, future prospects may depend on a prevalent philosophy among university researchers, namely, that they are not the most effective in responding to predefined problem statements on societal problems. Many researchers feel that the environment established by rigidly defined problem statements could not be worse, that it tends to stultify creativity, and that they become circumscribed by administrative procedure. More will be said on this later.

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Urban Mass Transportation Administration Programs

The Urban Mass Transportation Administration research had its origins in the small test and demonstration programs that accompanied an emergency loan program inaugurated in 1961 under a provision of the Housing and Urban Development Act. Section 11 of the Urban Mass Transportation Act of 1964 authorized a modest follow-on in research and development, and a 1966 amendment to this act directed that a comprehensive research and matching grant program be initiated. In 1968 most federal urban transportation functions were assigned to UMTA, the organization now having cognizance over the Section 11 program of research and training.

The actual wording of Section 11 of the 1964 act provides a philosophical background:

> Section 11. (a) The secretary is authorized to make grants to public and private nonprofit institutions of higher learning to assist in establishing or carrying on comprehensive research in the problems of transportation in urban areas. Such grants shall be used to conduct competent and qualified research and investigations into the theoretical or practical problems of urban transportation, or both, and to provide for the training of persons to carry on further research or to obtain employment in private or public organizations which plan, construct, operate, or manage urban transportation systems. Such research and investigations may include, without being limited to, the design and functioning of urban mass transit systems; the design and functioning of urban roads and highways; the interrelationship between various modes of urban and interurban transportation; the role of transportation planning in overall urban planning; public preferences in transportation; the economic allocation of transportation resources; and the legal, financial, engineering, and esthetic aspects of urban transportation. In making such grants, the secretary shall give preference to institutions of higher learning that undertake such research and training by bringing together knowledge and expertise in the various social science and technical disciplines that relate to urban transportation problems.

Congress placed considerable stress on bringing together knowledge and expertise from various disciplines. Indeed this program was a pioneering one in this regard. In information provided for applicants other important objectives are noted:

1. To encourage the development of new and revitalized academic curricula designed to attract and to educate increasing numbers of professionally trained people for research and operational positions in the urban transportation industry;
2. To expand and strengthen the national capability for and to carry on high-quality research and analysis of problems in urban transportation and to provide expertise in urban transportation for federal, state, and local government needs; and
3. To assist in establishing facilities and activities that can be used by local, regional, state, and federal governments and private industry to help solve transportation problems in urban areas and eventually to make these facilities and activities self-sustaining by reason of their excellence and their involvement with local and regional problems.

The UMTA programs for support of research and training in urban transportation problems have had major impact on universities, but a rather more modest influence on urban transportation. More will be said of this differential later. At this point, the impact on universities will be examined. Why was it so significant? First, this was a grant program; and, thus, it encouraged the entrepreneurial spirit that lurks beneath academic robes. Second, it encouraged institutionalization under objective 3; and although this in itself may be questioned, the university participation in real-world affairs that was fostered brought excitement and challenge to teacher and student alike. Finally, and perhaps most important, it brought support to an area that academicians had long identified as one of growing national concern. To paraphrase the RANN problem selection criteria, there was a readiness on the part of scientific and technical workers to deal with urban transportation problems.

From fiscal year 1969 to 1973, the UMTA Section 11 program granted approximately $12.8 million. Fifty universities have been involved in either the research or training components. These are tangible indicators of what I will call internal impact.

Comment was made earlier concerning the effect of this program on urban transportation—its external impact. Here its influence appears to be limited, perhaps for the following reasons. First, the development of influential university programs takes time. Among the required components are top-flight professors, line of communication to top administration, quality students, respected outlets for research findings, and career tracks to receive graduates. Stated otherwise, external impacts will lag even with significant internal program stimuli. Also, the urban transportation field is developing so rapidly that it is difficult to identify and assign relative values to the forces behind this state of change. In other words, the level of effort involved here would be unlikely to produce a highly visible impact—the competition for visibility simply is too great.

Highway Planning and Research Program

A discussion of the Highway Planning and Research Program of the Federal Highway Administration requires rather more emphasis on history since it was the first transportation research program in this country. Prior to the 1960s the United States willingly provided resources for all aspects of highway transportation. The early thrust of highway building was the opening up of the country begun by the canal and railroad builders. Government was involved almost at the beginning, acting through the Federal-Aid Road Act of 1916 to launch a massive federal-state program of highway construction. But from the outset, federal and state officials felt that their knowledge concerning road building and the related planning and administrative tasks was inadequate. In 1919, Anson L. Marston of Iowa State College said, "There is a very urgent need for the immediate inauguration of scientific highway research in accordance with a comprehensive national program. The country is about to spend untold billions of dollars in the building of paved roads, yet there is a very serious lack of fundamental scientific data which are absolutely essential to the correct design and construction of these roads." This recognition of urgent need was to be the keystone of the most extensive transportation research program ever undertaken.

By the Hayden-Cartwright Act of 1934, the federal government provided for the expenditure of 1½ percent of the annual federal highway money for highway planning and research under what has come to be known as the HPR program. This generous and continuing funding led to an extensive federally coordinated highway research program with much of the research under state supervision, though often undertaken by universities—in particular by civil engineering departments at the various land grant universities.

NCHRP Report 55, Research Needs in Highway Transportation, provides one view of what has been done and what is yet needed in highway research. It notes that there has been a changing emphasis in research from the time that highways were needed to get farmers out of the mud to the time that they are a service function in a very complex social, industrial fabric. Research through the 1930s and 1940s was needed in all aspects of highway technology, but the priority questions were largely of the "how" variety. How do we build concrete roads that will not deteriorate? How do we stabilize existing materials and base courses? How do we determine the needed thickness of the flexible pavement layer?

In the decade of the 1950s the high-priority questions typically had a different emphasis. What is the rational method of determining highway capacity? What are the relations among speed, volume, and capacity on freeways? What is the optimum freeway network for a city? What is the developmental impact of major highways? It is important to note that many of the questions of the 1930s were still being asked since rigorous solutions had not been provided, but now many were beginning to suspect that (a) we could live without perfect and immediate solutions to all the "how to" problems and (b) we had better redirect more of our attention and resources to more pressing problems.

In the decade that has just passed, the emphasis shifted again. Do we need this highway at all? How can it be maintained? What will it do to the environment? Is it as safe as it should be? How effectively is it being used? And through much of this, the old questions continued to be asked and research continued to be directed at those problems as well.

Several important observations should follow this commentary on how the highway research philosophy and its emphases have changed over time.

1. Given the proper climate, a coherent, tenacious research community with instincts and assets for survival will develop.
2. Universities contribute to this community's survival assets through the incestuous tendency of professors to reproduce themselves in the person of their best graduate students. (It is important also to note that the ever-expanding highway program provided rewarding career tracks for the thousands of graduate student-researchers supported by HPR funds.)
3. This sustained but flexible effort has had a high level of overall research productivity in spite of, or perhaps because of, the extensive institutionalization that developed.

To state the philosophy of the HPR program in simple terms, it is to enhance and thereby promote highway transportation.

The internal and external impact of highway research by universities has been enormous. Externally, it has contributed in an integrated fashion to the development of the world's finest highway transportation system. Internally, it has provided massive, continuing funding that has attracted outstanding professors and students, made possible up-to-date laboratories, supported numerous scholarly journals, and supported workshops, seminars, national meetings and conferences (including the Transportation Research Board). In short, it has had positive payoffs within its frame of reference. (The massive funding involved must not be underemphasized in a consideration of this program's impact. To illustrate, Pennsylvania's HPR program in fiscal year 1972 totaled $9.6 million.)

The more than $200 million of HPR money that has been spent in transportation planning since 1962, and the dominant influence of that planning on urban transportation, is perhaps an appropriate illustration of the external impact of this program. This money was, of course, not spent by universities; its spending was, however, dominantly influenced by HPR-supported research.

As noted at the outset, the HPR program is tied to federal construction expenditures for highways. Its status is, therefore, rendered uncertain by indecision over Highway Trust Fund diversion, by actions taken to reduce fuel consumption since all money comes from highway users, and most important by changing public values.

National Cooperative Highway Research Program

According to its 1972 annual report,

> The National Cooperative Highway Research Program is supported on a continuing basis by funds from participating member departments of the American Association of State Highway and Transportation officials....Each year AASHTO refers to the NCHRP a research program that consists of a group of high-priority operational problems for which solutions are urgently required by the member departments of the Association....Those contemplating proposals are advised that the NCHRP is a program of applied contract research; it does not function on a grant basis....Proposals are desired only from agencies having strong capability gained through the extensive successful experiences in the subject problem areas....It is expected that the personnel constituting this high level of capability will be used extensively in meeting the commitments of the proposal—capability cannot be developed at project expense.

The National Cooperative Highway Research Program was established in 1962 to provide for a continuing program of highway research. As noted above, problems come from AASHTO members, who contract with the National Academy of Sciences to commit

$4\frac{1}{2}$ percent of their $1\frac{1}{2}$ percent federal-aid highway planning and research (HPR) funds to this program. In this way a continuing annual budget of approximately $3.5 million is provided. The philosophy of this research effort, evident from the above statements, is essentially one of satisfying the sponsors—50 member departments of AASHTO.

This has been translated into specific operational concepts, e.g., applied research on operational problems by experts working under tight contract agreements. Other elements of NCHRP philosophy include careful attention to problem statements by a panel of experts, significant size contracts, close project monitoring, and rapid dissemination of findings.

By 1973, some $28 million had been expended on 203 projects in 24 program areas. Some 14 projects were advertised per year, each attracting an average of some 12 proposals. The spectrum of highway concerns covered by this program and the level of university involvement are given in Table 1. From this a significant impact on university research is evident. Educational institutions have been the most heavily involved class of agency, accounting for 40 percent of all projects (research institutes account for approximately 28 percent, and industry, consultants, trade associations, and others for approximately 32 percent). This significant amount of university funding in spite of the rigorous terms and conditions is worth noting.

During 1972, the program went through a period of uncertainty while the federal-aid highway act was delayed. This served to emphasize that this program is tied to traditional state-federal highway construction funding programs—programs in transition as noted in the previous section. In 1973, some 9 new project proposals having an estimated cost of $1.2 million were solicited. Three of the projects were directed at studying and modifying the traditional urban planning package, cited earlier as being a product of HPR research.

Program of University Research

The Program of University Research (PUR) of the U.S. Department of Transportation was announced in September 1972, so its history is brief. President Nixon's promise to reorder national priorities provided the basic impetus. In his 1972 message on science and technology he said:

> We must appreciate that the progress we seek requires a new partnership in science and technology, one which brings together the Federal Government, private enterprise, state and local governments, and our universities and research centers, in a coordinated, cooperative effort to serve the national interest.

Regarding philosophy and intended thrust, there have been extensive communication efforts by the transportation department. At the inaugural ceremonies for this program, the Secretary of Transportation said:

> Brainpower, pure and simple, is absolutely vital in these most complicated times in which we live. I would like to discuss with you briefly the nature of some of the broad, interdisciplinary problems affecting the vitality of national transportation and to emphasize the urgent need for universities to tackle some of these problems while they fulfill their classical, educational responsibilities.
>
> Society needs a new quality of excellence, an incentive to weld academic idealism to innovative research that will serve our country. So let me pose a challenge: that your works be directed toward improving the quality of our society.
>
> Your government has a great deal of confidence in the ability of universities to accept this kind of invitation and to make constructive contributions to our national life that transcend the education of our young. Your contributions are especially needed in transportation.

The research objectives of this program are as follows:

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1. To stimulate relevant, high-quality, and innovative transportation research at universities for the creation of new concepts, techniques, and knowledge;
2. To increase the effectiveness of universities in helping to solve local, state, and national transportation problems;
3. To encourage the use of modern tools of analysis, planning, and management, of new technology, and of professionally trained people by state and local transportation agencies;
4. To stimulate industry and state and local agency sponsorship of university-based transportation research; and
5. To assess the demand for professional manpower in transportation and to project future training requirements.

Broad-gauge transportation research not in conflict with that sponsored by the modal administrations is intended. It can be supported under 4 program elements:

1. Major research by interdisciplinary teams;
2. Project research, joint ventures with the local transportation community, both local government and industry;
3. Individual research by single faculty members and their students; and
4. University-based seminars to foster interaction between the university and the transportation community.

The earlier-noted readiness of the academic community to engage in transportation-related research was dramatically underscored by the response to this program. For the total funding of $3 million in fiscal year 1973, 723 proposals were received. Contract awards were made in response to 49 of these proposals. Therefore, current probability of success is very low indeed—an obvious source of discouragement to prospective researchers.

Already the internal (to universities) impact of this program has been large. The number of people devoted to writing the 723 proposals is a somewhat unhappy testimony to this fact. Future impact on universities is uncertain, but it is likely to increase. This prediction is based on the following:

1. The program is positioned in the top transportation office, and so will command money and attention;
2. It stresses interdisciplinary approaches; and
3. University-industry-government working alliances are encouraged.

Some $3.5 million was awarded on fiscal year 1974 funds. The present intent is to go to Congress for $6 million for fiscal year 1975. Table 2 gives information on the 1973 program.

SUMMARY OBSERVATIONS ON CURRENT PROGRAMS

These brief reviews indicate that there are several fundamentally different approaches to transportation research. They can also be used to support observations on several university-related issues.

Freedom in Problem Definition

UMTA, HPR, and PUR offer considerable freedom to the researcher in defining the problem he or she wishes to address. The research community makes much of this freedom, as was noted in the section on the RANN program, on the premise that responding to a predefined problem statement is destructive of the creative environment that universities should offer. RANN and NCHRP do, in fact, work entirely from sharply defined problem statements, and there are those in the university community

Table 1. NCHRP projects at universities from fiscal year 1963 to 1973.

Research Area: General	Research Area: Specific	Number of Projects	Number at Universities	Total Funding (millions of dollars)	University Funding (millions of dollars)
Design	Pavements	25	15	2.16	0.97
Administration	Economics	12	7	1.09	0.46
Traffic	Operations and control	21	5	4.80	0.79
Materials and construction	General materials	15	9	1.26	0.77
Traffic	Illumination and visibility	12	7	1.70	1.26
Maintenance	Snow and ice control	12	3	1.14	0.34
Transportation planning	Traffic planning	9	1	0.80	0.10
Transportation planning	Urban transportation	14	6	1.74	0.76
Materials and construction	Bituminous materials	4	1	0.33	0.11
Materials and construction	Specifications, procedure, and practice	11	3	0.83	0.10
Administration	Law	18	3	0.28	0.07
Design	Bridges	15	7	2.40	0.72
Maintenance	Equipment	1	0	0.02	0
Maintenance	Maintenance of way and structures	3	1	0.50	0.10
Design	General design	7	3	1.13	0.29
Design	Roadside development	3	1	0.32	0.22
Traffic	Safety	3	0	0.37	0
Materials and construction	Concrete materials	2	2	0.40	0.40
Administration	Finance	6	0	0.38	0
Special projects	—	13	4	2.70	1.30
Soils and geology	Testing and instrumentation	3	1	0.13	0.03
Design	Vehicle barrier systems	2	0	0.15	0

Table 2. Research categories in contracts and proposals of Program of University Research.

Category	Frequency Distribution[a]: Contracts	Frequency Distribution[a]: Proposals
Type of research		
Basic	25.8	17.7
Applied	45.2	45.7
Exploratory development	11.3	14.9
Advanced development	3.2	5.7
Prototype DT&E	0	3.4
Preliminary OP dev and demo	6.5	4.9
R&D support	8.6	7.8
Mode of transport		
Air	0	8.2
Guideway/rail	7.9	10.8
Highway	11.1	22.1
Marine	3.2	3.2
Pipeline	1.6	0.9
Intermodal	20.6	13.3
Multimodal	44.4	31.1
Other	11.1	10.4
Research objective		
Improve capacity and service	25.0	30.1
Reduce costs	8.8	13.2
Protect environment and conserve energy	16.3	16.9
Improve safety	11.3	14.2
Improve future options	27.5	18.8
Improve R&D payoff	11.3	6.8

[a]These numbers represent the times (frequency) that these categories appear in the contracts rather than a distribution of the contracts among the categories. They have been normalized on a scale of 100, and the numbers are not whole numbers.

who find this quite acceptable. Indeed, the high level of involvement of universities in NCHRP and the wide recognition of this program as a productive one argue in favor of this approach. Finally, those programs with a high visibility before state legislators or the Congress find that careful attention to problem definition is necessary if the work is to be directed along lines that will generate continuing support.

Continuity and Adequacy of Funding

The HPR program has enjoyed the greatest continuity and perhaps the most adequate funding. NCHRP is similar on both counts. The other programs described here are newer ones, responsive to a high need awareness. One might suppose that as long as this need persists they will have adequate funding, but that they are unlikely to have the continuity or to become institutionalized to the degree of the earlier mentioned programs.

Institutionalization

It belabors the obvious to note that the oldest programs tend to be the most institutionalized. But this institutionalization is so significant that it deserves mention. It touches on aspects such as reviews for the granting of research by friends and acquaintances, reviews for publication in the same way, well-developed bureaucracies for handling paper work, and well-known expectations regarding the product. As has been noted, however, it is risky to pass judgment on the pervasive institutionalization accompanying highway research since it cannot really be separated out as a factor in the high productivity that this program has enjoyed.

Interdisciplinary Approach

The newer transportation research programs (UMTA, RANN, and PUR) emphasize the bringing together of various disciplines. This is essentially contrary to the traditional university organization. The resulting structural and intellectual barriers probably cause interdisciplinary research to be less cost-effective in terms of short-term objectives than that within a single discipline. Experience and a wider frame of reference for evaluation are working for positive change here.

Requirements for Response

NCHRP has the most stringent response requirements. Research packages are large, funding is tightly fixed, problem statements are very specific, contract requirements are exacting, and demands on the research team are high. Nevertheless, university researchers have accommodated to this program, and it has been a productive one. With the growing requirement for interdisciplinary activity and for attention to real-world problems and the great competition for funds, all of these elements are likely components of future research programs.

Real-World Interaction

PUR places the sharpest emphasis on real-world interaction and linkages. The UMTA program also encourages a degree of institutionalization so that universities can become involved with local government and industry. The university context is not well suited for such real-world interaction, but for those who survive the frustration of doing it there are the rewards of enriched teaching and more relevant research.

Prospect for Implementation

NCHRP has placed great emphasis on implementation. Indeed its annual report calls out examples of implementation in great detail, this being the evidence of cost-effectiveness. Implementation is important not only for the customer but also for the self-satisfaction of the researcher. It seems likely that broad multimodal programs will cause implementation to be rather more difficult. PUR, for example, is so broad in scope that it may be difficult to trace a project from the secretary's office to where implementation occurs and to maintain communications along this channel so that there is a feedback loop.

CHANGING VALUES

The implication of changing societal conditions and values for the various functional areas of a society is a popular topic for professional futurists. The predicted implications for transportation, for example, of an energy shortage, of the new environmentalism, of coming economic conditions, and so forth range from utopian to Orwellian. Perhaps the only safe statement here is that society is departing at some unknown rate in a largely unknown direction from an approximate 50-year period of almost total automotive dominance and that certainly there will be repercussions in transportation research.

In a summer workshop in 1973 at M. I. T., Marvin Manheim listed changing societal values as being among the reasons why a systems analysis approach to transportation is needed; his point was that a fluid value system (together with rapidly changing technology and changing demand) calls for a swift, comprehensive, flexible analysis methodology. Certainly these same traits must characterize our approach to future transportation research programs. Indeed our research must be so forward-looking that it contributes to an understanding of this very societal value system!

In a time of rapid change our instincts are to concentrate on preserving our projects and programs. This is, of course, the very antithesis of broad-gauge creative research. At the same time there must be some base that provides continuity, that essential minimum context.

BEYOND CURRENT PROGRAMS

Acknowledging that changing values presage major changes in transportation research, what are the trends that indicate the future in our area of concern?

Institutional change perhaps provides the most illuminating trend in this regard. Apart from the creation of the U.S. Department of Transportation, the most significant institutional change is the move from state highway departments to state departments of transportation. To illustrate the significance here, virtually all of the departments provide for multimodal transportation systems planning. However, arrangements for the funding of such planning are in embryo stages of development, for until recently only highway funding, HPR money, existed. Pennsylvania, for example, initiated a study focusing on rail transportation needs but touching on modal interface aspects. To support the study, ad hoc funding arrangements had to be worked out between the various modal administrations in federal and state government. The old institutional channels did not fit this new type of project. Parenthetically, perhaps an even more serious problem is that the old institutions will still be there after a successful bypass has been devised.

Evidence of new institutional arrangements also is provided by the developing responsibilities for transportation, in a rather direct fashion, of the Environmental Protection Agency. If, in fact, air quality requirements are rigidly enforced, then the options for transportation may come to be dictated by this constraint rather than by transportation needs per se. The critical research areas then will derive from EPA requirements rather than from traditional transportation needs. Undoubtedly, there will be confusion before such a change can be translated into working arrangements for university research.

Another illustration can be drawn from the energy situation. If we take seriously the constraints on oil supply, then energy consumption, probably translated into cost, becomes the dominant criterion for transportation investment. Again research will be motivated primarily by this constraint and very likely will be administered in a new administrative framework.

Clearly, then, the institutionalization that has provided security for university researchers and has in many cases promoted productivity is breaking down. A research "ad-hocracy" will likely follow: programs established in response to specific societal needs, funded at the level necessary to produce the desired product, tightly controlled by agency monitors, changed or terminated when productivity lags or needs change. The UMTA reevaluation after a relatively short time perhaps illustrates this approach.

How should university researchers respond? First, I suggest a pragmatic acceptance of the trends noted above. Our pressing societal problems must be addressed by university and other researchers in a businesslike fashion, drawing on the wealth of basic knowledge that now exists. However, I also would urge a concentrated effort to preserve programs with freedom of inquiry, programs where evidence of creativity is one measure of success. This latter can be approached in several ways: through lobbying with stress on past accomplishments, but also through demonstration, with careful attention to productivity in all university research. Both of these should be pursued.

Professional Education in Urban Public Transportation

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In the rapidly developing field of urban transportation, the need for a practicing professional to continually update his or her knowledge and skills is critical. Those holding positions of responsibility, whether in the planning or operation of urban transit systems, are increasingly required to possess a knowledge of the latest methods of transportation planning and management, a familiarity with the latest technological developments, an understanding of the role played by transportation in the functioning of urban centers, and an awareness of modern methods of analysis and design. Yet the pressure of daily responsibility, the difficulty of initiating self study, the increased rate of growth of technical knowledge, and the change in character of technical and planning education make it difficult for the individual to fulfill these needs.

A 6-week course, developed by the Transportation Research Institute of Carnegie-Mellon University, offers the practicing professional a comprehensive overview of the urban transportation field and provides unique conditions for interacting with his peers. A wide range of topics is covered, much like those in a typical graduate program, but within a time frame that permits the participant to leave his or her place of employment on a full-time basis and return without excessively disrupting the continuity of work assignments.

There is recognition of the special need in urban public transportation for on-site study of new applications and practical results to supplement academic training. Accordingly, the program is structured in 2 parts. Part 1 consists of graduate level lectures and assignments, a series of seminars planned and conducted by participants, and several tours of local transit facilities. Part 2 consists of a lecture-study tour of major North American and European cities where significant transit developments are occurring.

The on-campus lectures in part 1 are grouped under 4 functional headings: planning, technology, management, and quantitative methods. The specific topical content of the 4 areas and the time devoted to each have been continually revised in response to detailed comments made by participants and to changing interests of the transportation profession. Instructional methods have also evolved. Seminars, panel discussions, and case study exercises provide opportunities for participant involvement.

On the lecture-study tour, the typical program in any city consists of a 2-day visit devoted to lectures and visits to transit systems. Examples include old systems in Paris and London, results of organization and integration in Hamburg and Munich, new

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transit systems in Montreal and Rotterdam, transportation and land-use planning in Stockholm and Runcorn, bus and tramway system developments in Rotterdam, Munich, and Gothenburg, and transit solutions in medium-sized cities such as Gothenburg and Bremen.

First offered in the fall of 1970, the program has been given each year thereafter. As of 1973, there have been 176 participants, representing 87 public agencies and 5 private firms. The former have comprised state, local, and regional planning and operating agencies, and, together with the private firms, are located in 22 states, the District of Columbia, Puerto Rico, and Mexico. Participants have represented a broad range of planning and operating positions at predominantly middle and upper management levels of responsibility. Participation in the program has been largely supported by the Urban Mass Transportation Administration under Section 10 of the 1966 Amendment of the Urban Mass Transportation Act.

Program participants have responded favorably to various design features that allow for greater interaction among participants and faculty. Many have commented that the most educationally valuable experience was provided by the opportunities to share common interests and to learn about activities in allied disciplines from other practitioners, including fellow participants, on-campus faculty, and professional counterparts met during the lecture-study tour.

This points up again the need for mechanisms whereby professionals of various disciplines can work together over an extended period of time to better understand one another's perspectives, problems, and points of view. This cannot be overemphasized in an era when transportation solutions are no longer viewed in a technological framework but incorporate many viewpoints and are characterized by diversity. At the graduate level, universities attempt to simulate interdisciplinary teamwork through project courses and interdisciplinary research. The mechanism for accomplishing this at the professional level is demonstrated to be through academic programs that accept persons who have a wide variety of backgrounds but common objectives and needs for professional training.

The strong endorsement of the lecture-study tour segment by participants supports the original view of the program designers that field study of a practical nature, representing material that could normally not be furnished directly by a university, would be essential for a program of this type and that visits to principal cities where innovative work is under way in solving critical urban transportation problems would be an essential element of a successful program.

The major task in a program of this nature is improving communications between participants and lecturers and among participants so that each has the opportunity to express his or her views, needs, and desires and to fully contribute to the educational experience gained by all. Obviously a group of this type is highly verbal and represents a wealth of experience and a body of knowledge that should be incorporated within the program.

A program of this nature can be practical while retaining its academic integrity. There is no value in describing theoretical and mathematical models that neither work nor have direct applicability to specific problems or in describing theoretical methodologies when the participants are eager to learn new ways of solving their current critical problems.

Two devices that appear to be successful in further defining the application of fundamental areas to specific problem situations, as well as providing greater opportunities for communication, are the case study and the seminar. Case studies have been used, particularly in the management area, to supplement or replace classroom lectures. The seminars involve topical presentations and discussions by the participants with the assistance of faculty or other experts in the field.

During a time when graduate enrollments are declining and the need for individuals with advanced training appears to be diminishing, many practicing professionals can greatly benefit from advanced university training. Special academic programs designed to meet these needs are one of the responses of the university to its responsibilities of furnishing high-level academic training to all segments of society.

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Content Problems in Transportation Education

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Academic programs should be evaluated on a regular basis to determine their future direction or viability. The following questions should be asked to help determine whether to maintain, initiate, or eliminate academic programs (1).

1. Is the program academically important?
2. Is there now, and will there remain, significant student interest to warrant continuance of the program?
3. Is there a high probability that the program will achieve a high level of excellence?
4. Is there a high probability that the program can be adequately and securely financed?

Program development depends, to a large degree, on our own experience and our own inventiveness.

OBJECTIVES

The primary objective of graduate programs in transportation education is to prepare broadly educated and well-trained students to deal with the complex problems of transportation in urban and rural areas. A distinction should be made between education and training. Education normally is associated with the process of imparting knowledge, while training connotes instruction and practice to develop proficiency. In the evolutionary period of program development, emphasis is placed on training students by teaching empirically developed working solutions to specific problems. This approach requires a great deal of time and effort to provide the necessary information for a comprehensive approach to transportation problems. On the other hand, the approach that broadly educates students by emphasizing planning and socioeconomic fundamentals is quite unsatisfactory. Therefore, an appropriate program will focus in between these 2 extremes and develop a balanced education that will provide sufficient background in transportation to yield understanding of its inherent characteristics and make available all the tools that may be required to attack its problems and lead to comprehensive problem solutions.

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An effective educational program must prepare the student not only for the first position he or she will have after graduation but, more important, for major responsibilities he or she will assume at some time in the future. The education should therefore prepare a student to become an effective decision-maker without the need for a vast amount of experience upon which to base the decisions. In developing an educational program, we must be concerned with the problems and issues that transportation will face in the future. The subject material should be as time-independent and as flexible as possible to provide the student with the capability to adjust to the rapid development of technology and of social change (2).

Ideally, the transportation student should achieve adequate preparation in mathematical and other analytical techniques; substantial knowledge of the concepts of, techniques for, and introductory experience in synthesis and creative design; and serious acquaintanceship with the socioeconomic aspects of urban functioning and their effects on or reactions to the development of transport systems (3). An understanding of the social problems of a community is essential to the analysis of the transportation needs of the community. The engineering aspects of the problem should not minimize or preempt the social aspects.

PROGRAM CONTENT

A basic aspect of the programs is to provide students with the analytical capabilities necessary to take into account and evaluate the many interrelated factors that affect the planning, design, and management of transportation systems. It is useful to distinguish between planning and design. Planning emphasizes the process of conceptualization and delineation of an overall system and the designation of the characteristics and interrelations of the major components so as to optimally meet the objectives for which the system is to be brought into being. Design emphasizes the choice and specification of details necessary to meet performance requirements, especially of the components of a system. These 2 phases of the process of creating a system merge, and sometimes detailed component design must be completed in order to proceed effectively with overall system planning (4).

A basic program will consist of courses dealing with (a) the planning of expressways and street grids, passenger and freight terminals, and transit and (b) the nature and control of the traffic that uses these facilities. These topics involve the analysis of the quite complex, usually stochastic, processes that arise from the wide range of time, mode, and routing choices available to travelers. Therefore, the student must acquire a working knowledge of probability, statistics, and optimization techniques, which together are referred to as operations research or system science. These quantitative techniques should be emphasized as proper subjects for minor concentration.

Stated simply, these techniques require the orderly investigation of all components that are interrelated to perform a given function. The foundation of system engineering is based on 3 fundamental ideas.

1. Interdisciplinary teams were formed to handle problems that were complicated by complex interactions among components of the total system. A thorough understanding of this cause and effect relation that exists among the various components of a system is therefore an essential step in solving any engineering problem.
2. Since system engineering attempts to solve problems from many different fields, it must be able to describe different physical systems by some common language. This is accomplished by mathematically modeling the system to be studied. Since the system engineer deals with a mathematical model and its properties that are essentially divorced from the complexities of the actual physical system, this approach can be effectively applied to countless engineering problems. These concepts have provided engineering with one of the most significant advances of modern times.
3. The concept of optimization underlies systems engineering, that is, optimizing the performance of the system as it is measured by some performance criteria.

The first step in solving any system problem is to state the set of goals to be accomplished. These goals or specifications then define the problems that must be solved before the goals can be realized. The overall problem is then broken down into solving many smaller but not necessarily less complex problems.

These problem statements define the set of solutions that satisfy the system's specifications. Because of physical or economical constraints, several solutions are eliminated. The engineer is free to select from the remaining subset the design that optimizes the performance measure.

In summary, the system engineer approaches problems from an optimization point of view. That is, the system is described analytically by a set of cause and effect relations whose parameters can be varied to optimize a particular measure of effectiveness.

The transportation planner student should acquire a working knowledge of system analysis and should be exposed to a meaningful, workable, integrated professional and theoretical approach to transportation problems. Both approaches are essential and, until articulation of each is achieved, transportation system planning will not be completely effectual. The transportation engineer student should broaden his or her background from purely functional considerations by undertaking some work in urban ecology, sociology, psychology, political science, and economics.

DISCIPLINES INVOLVED IN TRANSPORTATION

It is difficult to think of a discipline that is not involved, to some degree, in transportation, for its complexity requires interaction of many professional inputs. Political science, social science, management, law, finance, engineering, architecture, planning, and even medicine are intimately involved in decision-making in transportation. The interaction of decision-makers in these disciplines with the professionals in other areas of transportation is particularly vital, for it provides the decision-makers with all of the necessary inputs. Many disciplines do not recognize the need for interaction, others cannot communicate with each other, and few understand one another's concerns (2).

CONSEQUENCES ON SOCIETY

To satisfy the needs of society will require improving existing transportation facilities and building new facilities for public and private transport. Facilities must be operated so as to provide the largest possible free flow of traffic. But if a reasonable level of amenity is to be maintained, the added facilities must be planned to make a sparing and efficient use of land, to be convenient to use, and to make a positive aesthetic contribution to the environment of both users and bystanders.

Society is ever more committed to these goals; it demands increasing care and professional competence in the planning and operation of highways, airports, public transit, and goods terminals. Society, however, does not speak with one voice in expressing its desires as can be attested to by anyone who has attended a public hearing. Usually, there are as many diverse opinions as there are organized groups within a community.

Designers must not only conceive, design, and implement technologic systems of however great complexity but also fit these systems into the social, economic, and physical environments in such a manner that the quality of life will be improved for all. Unfortunately, we do not now fully have the capability of accomplishing this, and one of our greatest challenges, particularly in transportation education, is to devise programs and processes that will provide this capability.

The analysis of the performance of a proposed new transportation system should include prediction of consequences that will result as it functions in the different environments (social, economic, and physical) and prediction of the functional performance of the system. A basic technical problem for designers is to predict, with some reasonable degree of accuracy, both the internal performance and the external consequences of the systems they devise. But the fundamental and crucial problem is to get agreement on the goals and objectives of a community and to state them in terms amenable to analysis.

AESTHETIC CONSIDERATIONS

Unfortunately, inadequate attention is devoted to aesthetic considerations in the design and planning of transportation facilities. An indication of concern on the federal level was the establishment of a Commission on Highway Beautification under the Federal-Aid Highway Act of 1970. As stated in the legislation, the duties of the commission are essentially restricted to the problems created by outdoor advertising signs and junkyards. Highway beautification is not related to highway location. The commission's charge is extremely narrow and is indicative of the lack of a comprehensive approach to the problem.

Historically, the impetus for the development of comprehensive transportation planning programs has come from the national level of government. This does not mean that state and local governmental units should abrogate their responsibilities. On the contrary, they should intensify their efforts with the economic support of the federal government.

Academic institutions are equally remiss in recognizing the necessity for curriculum changes. Professional growth begins during the period of formal education. The concept of "better design," or the more general concept "aesthetics," is almost nonexistent in the curriculum of the undergraduate engineer. It is also sadly lacking in the graduate engineering curriculum. When a road, bridge, railroad, airport, or seaport is constructed, the ultimate appearance is purely a result of structural design and the engineer's judgment (and the functional requirements of the facility). No thought is given specifically by the engineer to appearance, and no thought (other than functional considerations) is given to how the facility fits into the neighborhood, area, city, or region of which it is a part. At best, the engineer or engineering firm will hire architects to "dress up" the project.

The starting point, then, is at the undergraduate level, where an appreciation for form, composition, and relations of materials to purpose is difficult to find in most U.S. engineering programs. This is not the case, however, in some foreign countries, especially in Italy and Belgium, where there is less separation between the engineer and architect. Universities in Italy invariably include required courses in technical architecture, architectonic design or architectonic composition as requirements in those civil engineering programs leading to specialization in construction or building. In addition, city planning is also included. All of these course requirements lead to an appreciation for form and for the applicability of various materials to specific situations and to an understanding of the effect of a project in the context of the city and the neighborhood.

In Belgium, one may receive a degree as civil engineer-architect or civil engineer-building. The student civil engineer and student engineer architect programs share the same required courses in architecture in the first 2 years, and the student town planning engineer and town planning architect share the same first and second year programs.

England and Germany seem to follow programs closer to those in this country. However, in the technical universities of Germany, city planning is offered by the faculty of construction engineering, faculties of architecture and civil engineering are often combined, and the faculty of civil engineering (University of Stuttgart) offers courses in architecture and landscaping (6).

We may all represent what Richard Gummere has called "the quiet revolution." Recognizing that a growing number of students are choosing to work with concrete materials rather than abstract concepts, he sees them rejecting the traditional subjects in favor of sculpture, painting, films, drama, music, and writing and thereby transforming the heart of the university—its curriculum. The curriculum has been overthrown 3 times during the 1,000 years of the universities' existence, and the provost of the State

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University of New York at Buffalo foresees a fourth revolution in which art will replace science at the center of higher education. So we can take satisfaction in the knowledge that our interests are in the forefront of revolution, even if we are middle-aged and part of the establishment.

An appreciation for the problems of aesthetics (and this may include more than visual aesthetics; noise and air pollution can insult other senses as much) will perhaps lead to a greater acceptance of the design team concept. The need is long with us; the effects of introducing highways into neighborhoods in the name of slum clearance or urban renewal are long since discredited.

Multidisciplinary interaction is essential to obtain balanced and mutually reinforcing solutions to transportation problems. Many major urban transportation projects are planned by using the design team concept. The team is usually composed of civil engineers, structural engineers, traffic engineers, architects, landscape architects, urban designers, city planners, sociologists, urban geographers, economists, applied mathematicians, lawyers, and market analysts.

Greater attention must be paid to the effects of the automobile and its necessary roadway system. Problems of congestion, air pollution, aesthetic pollution, noise pollution, and the disposal of discarded vehicles must be confronted by all those who have a hand in the management of traffic or planning for it. The future livability of city and suburb alike demands it.

A glaring example of the lack of attention to human needs is the inadequate consideration given to pedestrians. Transportation planners have been primarily preoccupied with system modifications and design to improve vehicular flow on street networks and into and out of terminals. They have given little attention to the plight of pedestrians on city streets and their movements between modes of transport. Very often a gain for the vehicle results in a loss for the pedestrian.

Walking is the most basic, common, and neglected mode of transportation. Consideration of the concept of aesthetic design for transportation cannot ignore the age-old ambulatory mode. The difficulty lies in its very universality. The concept of aesthetic design for the pedestrian, therefore, resolves itself into the general aesthetics of the pedestrian environment, which is generally the entire city, and specifically the immediate street or transportation facility.

We can hope that the facility will not obstruct pleasant views, create nuisances (and health hazards) of noise and air pollution, or disrupt the physical homogeneity and basic concept of a community. And again, minima are inadequate to convey the full range of need in changing the basic viewpoint of the engineer who will in some way change the environment of the pedestrian.

CONTINUING EDUCATION AND EXPERIMENTAL EDUCATION PROGRAMS

Although we must teach the student to cope with the rapid rate of obsolescence of his professional background, there is an indisputable need for carrying on extension programs such as short courses, conferences, and seminars. The need for continuing education is a recognized necessity, particularly in a dynamic field such as transportation. A forum is needed to provide for exchange of ideas among professionals, to acquaint transportation planners and engineers with new developments and techniques, to acquaint technicians with fundamentals, and to make civic-minded groups cognizant of the importance of transportation planning. It would be desirable to experiment with flexible programs of study in both duration and scope to accommodate a wider range of backgrounds of individuals who may wish to continue studies on a less formal and structured basis. It is also imperative to develop programs to achieve an articulation between engineering programs and nonengineering programs, such as science, law, medicine, business, management, economics, and social science.

Trends in graduate technical education indicate that substantial changes are taking place in the training offered by different institutions. Although classical training is organized along the concept of given disciplines, modern society requires knowledge;

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and training in many different disciplines related to a given problem, such as transportation, is paramount. These trends create problems at the graduate level. Efficient graduate education in applied sciences and technology requires concomitantly broad basic training and specialized training in advanced fields of technology. Such specialized training is now extremely difficult and expensive because it must be limited to small classes of students and requires very competent faculty members. Therefore, 2 opposing trends are developing:

1. Because of financial limitations, universities are reducing as much as possible specializations and diversifications in order to increase the number of students in any given curriculum; and
2. Because of continuing progress in technology, employers require graduates with a basic education in technical and nontechnical fields and specialized training in given fields of advanced technology.

Present classical educational programs are not suited to fulfilling such requirements. They are too expensive to the student and to the institution and do not have the capability of providing interdisciplinary education and specialized training. Specialized training, limited to a small number of students, can be best offered by combining research activities and educational activities and using new educational methods. Research activities in advanced fields are also the required basis for sound programs in continuing education. Curricula having a part of the training devoted to interdisciplinary education can be best organized outside of the classical departmental and school structure that is formed around specific disciplines, especially when all the required disciplines are not available in a single institution. Such requirements indicate that a different organizational structure, one that is formed around several groups performing large-scale organized research of an interdisciplinary nature, could better satisfy such demands.

ADMINISTRATIVE ORGANIZATION

Transportation education has its roots in civil engineering, and civil engineering curriculum has been modified to reflect an appropriate emphasis in transportation (7). I believe, however, that transportation education has developed to a sufficient degree that its umbilical cord should be cut. Since comprehensive transportation planning requires the inputs from a variety of disciplines, admission to graduate transportation education programs should not be restricted. Applicants should be accepted with degrees in engineering, science, and architecture or in programs that have major concentrations in areas such as social science or management.

The greatest potential for successfully achieving a multidisciplinary approach to transportation education can be created by a meaningful reconstitution of the academic structure and the development of a satisfactory decision-making process, which is a complex procedure in a university, involving a sophisticated sharing of responsibility between the faculty and the administration.

Martin (8) has written perceptively on the subject of organizational structure of engineering schools. Some of his cogent observations are given below.

> 1. Traditionally, the department serves as the basic unit for academic and research matters. This unit is effective where it covers a single discipline, but most departments, particularly those in engineering, are not structured about a single discipline. They are organized about a professional area that is multidisciplinary. Therefore, it frequently develops that several of these professional departments share a community of academic and research interests. These communal interests can act either to draw the departments together and to maximize interaction, or to make them compete for exclusive franchised rights in those areas of common interest. It is unfortunate that destructive competition nearly always ensues, rather than cooperation, and the departmental structure then becomes a barrier to appropriate interactions.
>
> 2. The role, scope, and scientific bases are changing for all the engineering departments, but

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constructive action to accommodate these altered conditions is paralyzingly slow in developing. Unfortunately, the history of academic departments is not one that reflects readiness to change, or willingness to permit a broadened franchise for another department.

3. While the traditional approach is undoubtedly inadequate, there is little prospect of abolishing the established engineering professional degree structure. Large professional societies, state registration laws, industrial organization, civil service classifications, and recruiting are all based upon the existing degree designations.

Virtually every effort to change this to any substantial extent has failed. Therefore, it appears most practical to retain the conventional engineering degree designations, but to consider a new structure for the administration of engineering education that leads to traditional degrees, but not exclusively through the traditional professional engineering departments.

4. It is becoming increasingly common at some schools to form interdisciplinary centers in some areas in an effort to break down departmental barriers. These are interdepartmental or interprofessional centers treating a single discipline or at least an area that is more homogeneous technically than a standard branch of engineering. By combining the residual departmental strengths through an interdepartmental center, the various isolated pockets of strength can be interconnected and coalesced to greatly multiply the strength existing when fragmented.

5. The faculty need two homes, a professional department and an engineering science center. This same duality of need appears in curricula, particularly in the undergraduate common core. In virtually all graduate programs, although the degree is sponsored by a professional department, the work occurs in an interdepartmental engineering science area.

Almost every aspect of the administration of an engineering school argues the need for a dual structure of professional departments and engineering science centers.

This provides the individual faculty member the maximum flexibility to develop his capabilities. His scope of interaction with other faculty members is substantially enlarged.

6. The division of engineering science into sectors of readily manageable scope is arbitrary and might vary in time and viewpoint. Therefore, in recognizing the dynamic nature of engineering science, room must be left for additions, courage must be used for deletions, and ingenuity should prevail for transference of concepts and principles.

To overcome the difficulties outlined above, the Institute of Technology at Southern Methodist University has developed a grid or matrix structure for its administrative organization. It is an excellent model that is innovative and worthy of consideration. The traditional professional departments form the vertical divisions of the grid, and the engineering science areas common to the professional departments constitute horizontal slices through the professions. All faculty members maintain joint appointments in a professional department and an engineering science center. Authority is divided between the professional departments and the engineering science centers as described below.

1. The basic budgetary unit is the engineering science center. Each center is responsible for the development and operation of all laboratories at all levels for all purposes, all courses of instruction, research activities, and all faculty acquisition and must assist the departments in the recruitment of graduate students. Recommendations for faculty promotions and salaries are determined primarily by the center directors. Centers offer courses and direct research, but are not permitted to offer degrees.

2. The professional departments are responsible for all curriculum matters, counseling and recruitment of both undergraduate and graduate students, and professional liaison. The departments are essentially committees representing the professional areas in which degrees are awarded and are drawn from the engineering science centers. Faculty performance in these departmental duties is appraised by the department head, and these appraisals are carefully weighed by center directors in making recommendations for salary adjustments and promotions. Departments award degrees, but may not offer courses.

I am aware that restructing the administrative organization is not the panacea to accomplish a multidisciplinary approach to transportation education, but I am certain that without it the task is even more insurmountable.

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Societal Contexts of Transportation and Communication

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Economic geographers and urban historians have known all along that the histories of cities have mirrored the histories of their transportation and communication systems. We all learned something about those causal relations in grade school. Most literate people have at least a vague notion why so many great cities occupy seaside or riverside sites, why Chicago happened where it did, why the suburbs are spreading in their current fashion, why the southwestern metropolitan areas are expanding today, and indeed why cities happened in the first place. Most laymen dimly remember those lessons about the roles of transportation and communication systems from Geography 1.

But, paradoxically, those of us who work as transportation professionals have become much too knowledgeable about the workings of transport subsystems to pay much attention to such large-system effects. Some of us have become sophisticated model builders who can simulate a network's loading with remarkable precision; others are superb geometric designers; others are becoming skilled at forecasting traffic; and some are now becoming sensitive analysts of environmental neighborhood effects of transport facilities. But where are the transportation planners who are concerned with the larger societal roles of transportation-communication systems? Where are the persons who worry about those outcomes of transport systems that really matter? Where is the effort to formulate national or state transportation policy—that is, policy for transportation services and for their consequences? As I shall try to argue, a plan that merely locates new transportation routes and facilities—whether roads, rail lines, airports, or similar public works—won't do it. Without a predecessor policy for the types, qualities, and distributions of services that are desired, such a physical construction scheme might be counterproductive; i.e., it might do more damage than good.

I say that because transport systems are powerfully influential in shaping social history—just as the geographers and the historians have been contending. And if they are right, we must then ask whether we might exploit them, instrumentally, as levers for deliberately reshaping social conditions. Can we use transport as one among the available means for redirecting city-development processes, for fostering economic development, for improving the life opportunities of the city's residents, for raising levels of the various publics' welfares? With all our newfound sophistication in the transport planning professions, can we now elect those of the potential external consequences of transport developments that we prefer?

That may strike some as a rather old-fashioned idea. At an earlier time, suburban

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developers used streetcar lines as sales devices, and trams thus became media for guiding urban expansion. Earlier still the Congress subsidized the construction of a national railway system with the aims of opening the western territories and promoting economic growth. The initial federal road program was directed to getting the farmers out of the mud and getting their crops to market. More recently the BART system was designed as an instrument for inducing growth of high-density business districts at several points around the San Francisco metropolitan area. There are surely other examples in which transport investments were directed to nontransport payoffs, but the surprising thing is how few contemporary examples we can find.

Transportation planning in America seems, inadvertently, to have pursued an adaptive strategy rather than an instrumentally purposive one. Moreover, the adaptations have been responsive, almost exclusively, to transport-specific demands rather than to the external societal ones. It is as though transportation planners forgot their original mission and grew to believe their business was to build transport facilities instead.

This propensity is most visible in the highway planning activities of recent times, although the tendencies are as firmly established in air transport, in seaport developments, and of course in passenger rail systems. In each of these modal spheres the responsible agency undertakes to forecast probable future levels of travel demand between pairs of places and then to design a physical facility with capacity sufficient to handle the predicted loadings. The transport planners' task is to accommodate those loads.

To be sure, some other criteria are imposed. Capital costs of the new equipment must be tolerable. Certain accepted standards for travel speeds and safety must be met, and of course structural design standards must be met as well. These criteria are all internal to the transportation facility itself.

Nowadays some additional criteria are being insisted on that are external to the facility per se. These include considerations of the neighborhood effects of noise, smell, vibration, and the like and consideration of the lost buildings that rights-of-way consume. Much of the recent citizen protest against freeways and airports has been directed against these sorts of first-round external social costs that fall out on adjacent properties and their inhabitants. In turn, these protests have compelled a revised perception of transportation systems, whose boundaries have now been stretched to include the neighborhood effects they immediately generate.

That strikes me as a salutary development in the right direction, but it is at best a modest step. However important those first-round, short-distance, short-run effects, they appear as trivial when compared with the large historic consequences we learned about in Geography 1.

SOCIETAL CONTEXT OF TRANSPORT TECHNOLOGY

The revolution in transportation and communication of the current century has been a key ingredient of the societal revolution that is transforming social organization, political behavior, structure of the national economy, religious practices, and family relations and furthermore transformed the traits of small-scale, early industrial society to those of large-scale, early postindustrial society. No aspect of the national society has been immune to the consequences of that quiet revolution.

Virtually all the technological developments in transportation and communications have had the effect of reducing costs of overcoming geographic space, hence of reducing the barriers to interaction that space has traditionally imposed. Improved ships, canals, railroads, automobiles and trucks with their associated roadways, the telegraph, the telephone, the radio, data-transmission systems, television, communication satellites—all constitute a family of progressively more effective erasers of distance. Each in turn has brought geographically distant partners into closer association, thus opening up the local urban systems to interaction with each other. By now, the entire nation operates as a single open system, indeed as though it were a single city. Business firms located on the 3 coasts interact with the ease of their nineteenth century counterparts located within the same town. Goods, information, and services are easily traded across thousands of miles, with the result that America has become a single, national urban system of tremendous scale. The progressive modification in the economic geometry of space has abetted a long-term shift toward greater social differentiation, increased complexity in the structure of the political economy, and new levels of social integration. By now, a degree of national integration has emerged, which is unprecedented in its spatial and temporal dimensions.

Of course it would be absurd to attribute the motive force behind the twentieth century nationalization of America to the transportation-communication systems that emerged then. That drama has been the resultant of the interplay among powerful arrays of influences, of which these systems have been but contributing aspects. Even though the revolution in transportation and communication has not been a sufficient cause, it has surely been a necessary contributor to the revolutions in societal patterns that have evolved during these past 70-odd years.

The new transportation and communication processes have been so thoroughly enmeshed within the processes of social change and the processes of economic development that it is probably impossible to distill out their specific roles. That is in part because all these processes are mutually interactive ones such that modifications in the technologies generate modifications in social relations that in turn generate further technological modifications. That sort of positive feedback amplification is a familiar one to development economists and to electronics engineers, of course, and is probably endemic to the workings of most open systems. The sheer complexity of interactions within such a causal network in the national urban system, however, has so far defied description, much less explanation.

The difficulty of explaining causal roles is then further confounded because the variables themselves become implicit functions of each other. When 2 mirrors face each other, is it possible to say which one generated the original image or which reflection belongs to which mirror?

The structures and functions that characterize contemporary Western societies, economies, polities, and geographies have been so thoroughly influenced by current transportation and communication technologies that both the societal and the technological phenomena must be seen as aspects of each other. This country's development has been so intimately involved with the automobile and the telephone that it is now impossible even to conceive of either except as an attribute of the contemporary culture. The automobile, for example, is now a functioning part of social systems, not a separable thing.

Of course, in the trivial sense the automobile remains a physically identifiable machine, complete with wheels, engine, and the rest. So too does the telephone with wires, switches, and so on. But, operationally, each is a working attribute of a high-scale society whose members interact frequently and speedily over large distances and for whom random access is a highly valued capability. Modern society might as accurately be named "automobile-telephone society" as "industrial-commercial society." Each of these names is descriptive. (Or perhaps "monetized society" is a more telling illustration of my point. The invention of money occurred so long ago that we no longer think of either currency or monetary institutions as technological developments. Each has been so thoroughly woven into the societal fabric as to have become a definitive attribute of that fabric and to have taken on the coloration pattern of its context. Can you imagine a modern society without money in some form?) I am suggesting that the automobile, the telephone, the television, the airplane, and the rest ought properly also to be viewed as an integral pattern within that same contextual fabric. Neither pattern nor fabric can exist without the other.

Seen within such a contextual frame of reference, it becomes impossible to discuss the impact of the automobile or the telephone on society. Such a formulation would presume linear, one-to-one, unidirectional causation. Instead, and at best, we might seek to expose the interplay among these mutually interactive influences. I have been trying to learn how to think about these phenomena in this way, and I must say that I find it difficult to do so. It is so easy to fall into the old conceptual trap of the mechanistic cause-effect link through which A impacts B to yield C. I am guessing that, in the complex world of social systems, A is defined by its interactive relations with both B and C—that A is a function of its environment and of the environment's future history.

Viewed from this perspective, the vernacular conceptions appear to have been far too simplistic, perceiving technological developments and transport facilities as hardware systems somehow tacked onto the body politic when they are really social systems buried deep under the political skin. When sober scholars are able to propose that the automobile or the freeway or some other widely used technological system be banned or otherwise excised from the social scene, apparently expecting the scene to be only moderately altered thereby, it would seem that their models must view technology as outside the social system. The paradigm I am searching for would obviously reject that perception.

To remove either the automobiles or the telephones would so transform geographic and social distances as to effect fundamental shifts in interaction costs and thus in the existing bases of the social order. Further, freedom to move and freedom to exchange information and knowledge would be greatly curtailed in the absence of equivalent technological means for travel and message transmission. Social and economic intercourse would thus decline, which would affect integration among establishments, and in turn affect the operating processes of the economic system, social relations, government, and so on. Technological systems, touching so close to the infrastructural bases of the society, can be excised or greatly modified only with large consequences for the rest of the social system.

You will note that I am not arguing that there are direct one-to-one cause-effect relations, such as the conception of technological impact implies. Nor am I saying that technology is causally neutral. Neither conception is tenable. The structures of society-technology relations more nearly resemble that of a complex, multidimensional web than that of a billiard table. In such a relational matrix some technological systems are so pervasive, so subtle, and yet so powerful in their roles as to comprise key traits of the social order they contribute to. I am suggesting that transportation and communication technologies are among the more pervasive, subtle, and powerful of the contemporary technologies. Moreover, their influences are far more profound than we learned about in Geography 1, for they extend much beyond their roles as shapers of cities and of social relations to include roles as agents in the contest for human welfare and social justice.

SOME ETHICAL ISSUES IN TRANSPORT POLICY

The magnitudes of transportation and communication installations in America have been well documented, and the scales must be generally understood. One out of every 6 jobs is directly related to production and maintenance of the stock of nearly 100 million automobiles, 20 million trucks and buses, and 3.7 million miles of roadway. Those roads carry well over a trillion vehicle-miles of travel each year. The 125 million telephones handle about 150 billion conversations annually, and the postal system handles some 90 billion pieces of mail. The scheduled airlines carry about 170 million passengers, who travel some 130 billion passenger-miles per year. And so on. Clearly transportation and communication are huge-scale activities. They are also very costly, consuming fully a fifth of the gross national product.

The development and installation of their physical facilities alone have of course generated large consequences that have reverberated throughout the political economy, propelling these sectors of the economy to positions of dominance. (Ten of the 12 largest industrial corporations in the United States are primarily engaged in producing automobiles, petroleum, or telephone equipment!)

The geographic consequences generated by the contemporary technology have of course been dramatic. First, all parts of the entire continental land mass were made operationally contiguous, thus permitting spatial dispersion of linked establishments over unprecedented distances. More recently the transition to postindustrialism has accelerated footlooseness; for information and knowledge are superseding bulk raw materials as the prime inputs into the economy, and these sorts of resources are of course easily shipped from place to place—whether on paper, wires, or embedded in human minds. As the result, factories, laboratories, offices, universities, and business-service establishments are discovering degrees of locational freedom that would have been unimaginable in an earlier stage of technological development. As noted before, the contemporary American political economy has been functionally integrated into a single working network such that nearly every firm in the nation is interlocked with all others in a complex web of mutual interdependencies whose threads connect nearly all persons and organizations in the country.

That scale of economic activity, that newfound locational freedom, that new ease of intercourse, and that nationalization have redounded as unprecedented standards of living for the large majority of Americans. Middle-America has finally attained the 2-car garage and the machines to fill it, the pot complete with 2 chickens, the suburban house, the long weekend, and, now, the growing guilt for having it all. But the guilt aside, few would willingly give it up for the life-style and the simple fare their parents and grandparents knew. Americans are comfortable and terribly wealthy, even the working class.

A great many are actively absorbed in the affairs of those interest-communities they happen to care about—church, professional society, hobby club, or American Legion post. Nearly all are tapped into the national communications channels in real time such that national and international events at least touch their consciousness, and nearly all share in the international recreation-sports-amusements-art-literature-music explosion that has become for many a paramount source of satisfaction and sense of achievement. Insofar as the transportation and communications technologies have contributed to that accessibility and thus to the current explosion in science and art, we must of course score them positively. And there can be no question about the beneficial roles of automobiles, telephones, campers, trailers, airplanes, boats, television, high-speed printing presses, and all the rest in the development of the new suburban life and the new recreational and intellectual opportunities.

But more important here is the parallel fact that these benefits have been unequally distributed among the nation's publics. More than that, because some sectors of the national population have benefited so greatly, other sectors have been positively hurt. Insofar as the new transportation and communications technologies have been major contributors to those inequitable outcomes, they must then be faulted and, I believe, corrective action should be taken.

Automobiles and telephones permitted spatial dispersion at the metropolitan fringe and thus were in some primal sense causal factors in the suburbanization of America. At least 2 further consequences of suburbanization worked positively to hurt those who did not enjoy the advantages of car-plus-phone.

The induced decline of public transit services has meant that those who do not have discretionary use of private cars are worse off because those who do have them are better off. Further, the massive restructuring of the metropolitan spatial patterns has meant a rapid expansion of jobs in suburban locations and the concentration of the poor in the old city center. Those who are constrained to center city residential locations are relatively inaccessible to the expanding suburban jobs. That fact is exacerbated by the geometrical asymmetry of public transit systems, which are ineffective at serving work trips originating in the center city but bound for dispersed suburban locations.

One consequence has been the further relative deprivation of those sectors of the population who are already relatively deprived, most notably persons who are poor, underskilled, underemployed, and underclass. If they happen also to be black, and thus barred from many desirable suburban residential districts, the shifts in spatial structure and the atrophy of public transit services have compounded their handicaps.

Of course, they are not the only ones who have been hurt by the twentieth century revolution in transportation and communication. The young, the old, the infirm, and others who either cannot drive cars or cannot acquire them have been similarly disserved by the shift to the automobile-highway system, however much they have profited from the increased access to information, knowledge, friends, and so on.

The black revolt of the 1960s and the middle-class citizens' revolt of the 1970s have made us all aware of these inequitable incidences of benefits and costs arising from changes in transport systems. Transport planners are now actively searching for a rationale in equity to replace or, at least, to supplement the engineers' traditional rationale in efficiency for testing alternative transport designs. Most officials in transport agencies by now agree that least cost solutions are not necessarily the right ones, that benefit-cost ratios are too gross a test (in part because they hide the distributional consequences), and that issues of social justice are of at least equal importance to issues of cost accounting.

In the United States, we are of course a long way from finding easy operational procedures that would respect those insightful conclusions. And I am guessing that our received professional paradigms are probably the most difficult obstacles in our way.

Those of us who were trained in the natural sciences and in engineering, and many of us who were trained in positivist social science too, were trained to believe that there are correct answers to problems. The frequency of the phrases "problem solving" and "optimization techniques" and the facility with which some can speak of "solving the urban problem" are dead giveaways. We truly believe there are right answers to be found, that there are optimum solutions to be discovered or invented.

I shall wish to argue that there can be no such answers or solutions to societal problems or to societal systems, including such societal systems as transportation and communication ones. The only tenable answers to questions are those that come out the other end of political processes. Especially where the outcomes are of the zero-sum sort, such that somebody loses because someone else wins, there is no way of knowing what is right. Indeed, there is no right. There are only political bargaining and the outcomes of those open political processes.

That may be the hardest lesson for scientists and engineers to learn. Contemporary and future transportation policy will specifically surround just these kinds of equity issues for which answers can never be found. We are in for a tough period of learning in the transportation professions, where our intellectual habits are mismatched with the contemporary problems of transportation policy.

That is in part why I suggested in my opening comments that we reconsider the idea of national and state policy plans for transportation-communication. It should be clear by now that I do not believe a simple cause-effect program-outcome plan is possible. Technology-society relations are far more complex than that. But transportation-communication policy can be consequential because these systems occupy so central and so powerful a set of roles in the workings of huge-scale societies, and especially in those of huge-scale postindustrial societies.

The national and state policy-planning style I dimly perceive would not be a scheme for the installation of facilities of various kinds. That kind of master planning may have its place somewhere later in the developmental process, but not here. Rather we need a set of synoptic policies that would seek to exploit potential new technological and institutional developments in transportation and communication for explicated social purposes. Likely candidate policies would be concerned with the further expansion of accessibilities to opportunities, including geographic accessibility and access through other routes such as improvements in cognitive, social, occupational, and artistic skills. (That is to say, transportation is only one of many means at our disposal for opening social systems and for expanding access to opportunity. It may not even be among the most effective ones.)

Clearly at the top of a policy agenda concerned with transportation and communications is the demand, among deprived groups, to redress the grievances that the rise of automobiles, telephones, suburbs, and the decline of public transit have generated. Something like half the national population does not have discretionary use of an automobile, and that condition obviously must be confronted.

The response is obviously not to "remember the answers" from the last century's approaches. Neither rail transit nor present bus systems are likely to satisfy latent demands for service. Instead, I suggest, the response should be a set of policy positions—a set of preferred functioning conditions—that might then guide large-scale research and development efforts to develop successors to the automobile. Such a new system would, in effect, be a better "automobile," but usable by those who are now excluded. I mean to say, it would probably have to mimic the present car's operational capabilities by furnishing random-access, door-to-door private service; and it would need to be safe, comfortable, and within the economic means of its intended users.

National and state transportation-communication policies of the sorts I am suggesting would initially be directed to the development of the nation and the regions—including their economic development, their revised geographic patterns, and the preferred pace and patterns of human development for the several publics. Those goals would need to be interpreted into levels and qualities of services to be provided, not hardware systems. The hardware systems ought then to follow in turn insofar as we have the capacity to design hardware systems to order.

Among the key demands we should impose on such a policy formulation is the demand that careful efforts be made to trace out and expose likely future consequences of each alternative explored, especially the distributional consequences that would allocate benefits and costs among the many publics that constitute the society.

We would wish then to generate political debate over these proposals and consequences, searching for the politically viable policy-program package. In a field such as this where there is no consensus on national goals and no consensus on the distributional equities, only political bargaining can yield acceptable decisions. The task of transportation and communication planners is to fuel that debate by supplying better repercussion analysis, better forecasts of likely outcomes, and sharper questions that will engage more publics in defense of their preferred positions.

Of course, those sorts of analyses and informational contributions cannot be politically neutral. Inevitably, whenever the analyst must select data or interpretations, he or she adds to the debate, affects the outcome of the debate, and aids one group at the expense of others. However dispassionate the analyst is and however disinterested in the outcome, by informing the debate he or she fosters one set of distributional consequences over potential others. This is to say that every technical analysis is inherently political in character.

And so, however distasteful the analyst-planner-designer-engineer may find the role, he or she cannot avoid being cast as a political actor and partisan. I mean that in 2 senses. Because the technical contributions of the analysis may help one group accomplish its purposes and deter another's from its, the analyst inadvertently becomes allied with one of the rivals. But, moreover, insofar as his or her contributions lead to the exploitation of some technological systems over others, the analyst also thereby becomes party to the social history that will follow, including the future history of equity or inequity. There can be no neutrality in such public affairs, and especially not in affairs that matter as much as these do.

I am suggesting that transportation systems are far more important to the processes of social change, to the workings of politics, and to the distribution of social justice than the transportation planning enterprise seems to recognize. If the large-system perspectives of Geography 1 were to inform a future national transportation-communication policy, perhaps the grossest latent inequities could be avoided. Perhaps we might even be able deliberately to open access routes to improved life opportunities. Or, if you happen to prefer different social purposes, perhaps the large consequences triggered by new transport and communication developments could be directed to accomplishing your ends instead.

It is in the nature of these systems that those consequential outcomes will be generated anyway, whether we like them or not. As agents in their design, transport planners will be causal agents of those consequences, whether they intend them or not. It strikes me that those conditions pose a problem in professional ethics from which there can be no escape.

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Shifting the Emphasis in Engineering Education

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Melvin Webber related a case of an elaborate public transit system that was designed for a city in southeast Asia. He cited the large number of studies and design reports prepared for this project and then indicated that the fare on this technically excellent system would be nearly equal to the daily wage of a typical worker.

We are concerned about the relation of engineering education to the institutional and cultural barriers that seem to inhibit a real consideration by engineers of nonfacility solutions to public problems. The public image of the engineer is that of a builder. Young people enter engineering colleges at least partly because they want to grapple with problems in the physical world in a satisfyingly visible way.

Until comparatively recently, there was honor enough in being a builder. But highway engineers, for example, are aware that they are now suspected by some of a single-minded desire to pave over America. Most civil engineers would agree that nothing in their educational experiences ran counter to the notion that the only function of the engineer is to create more and more physical property. Writers who picture the "engineering mind" as bent on constant rearrangement of the landscape may thus have a point.

We think that engineering educators should take the lead in bringing to their students and to the public as well a new concept of the engineer: not merely one who builds but one who is a steward of the physical environment and who knows when to build and when to try other solutions in which he may play only a part along with other professionals. It is not sufficient simply to expose engineering students to courses in social science. We must in our professional courses try to help students relate their technical knowledge to larger social and political realities. In an earlier day, engineers might be sure they were contributing to social welfare by building a railroad. Today they could not be nearly so certain that they were creating a net social benefit.

The institutional barriers to which we have referred stem from the traditional concept of the function of an engineer. For example, in most cases the engineer is paid for what he or she builds and is, therefore, biased against offering professional advice that does not culminate in a construction project. Anyone who has worked as a consulting engineer knows that clients do not often willingly pay the true cost of a study or report. There is a tendency for consultants to lose money on such work with the hope of recouping their losses by preparing project plans. We suspect that situations of this kind have influenced the decision to proceed with more than one marginal public project.

Product of the Transportation Education Process

Roger L. Creighton
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As a consultant, my interest in the transportation educational process focuses primarily on the type of trained person that emerges and becomes a part of a productive transportation planning organization. My viewpoint, although greatly tinged by my consulting experience, is also affected by previous experience with state and municipal governments and by recent observation of what various states need in the way of trained professional manpower. Any viewpoint on the type of graduate that is produced by a multidisciplinary education in transportation is also affected by the situation into which these new professionals will be moving.

The hiring agency recognizes that the university in 4 years of undergraduate work and perhaps 2 years of graduate work cannot convert a high school graduate into a mature and independent professional who is ready to take on responsibility for a project. The university can only start the growth process and provide the fundamentals that the new professional needs.

The hiring agency recognizes that it, too, has a continuing educational responsibility, in part because assuming that responsibility has a strong financial effect on its operations. The sooner we can develop a recent graduate into a person who can take responsible charge of a project and carry it through to completion (of course, with the support of other specialists in the organization) the better off we are. Hence we are extremely interested in training our people.

In this regard we believe that professionals will continue to grow as skilled technicians for periods of 10 or 20 years. The only limit on growth should be their own personal interest in growing. There is no reason why they should "dry up" after 4 or 5 years. Recognition of the possibility of continued growth is important because of the great complexity of the field of transportation planning.

In addition to recognizing the need for continuing training and the possibility of success in that line, both the hiring agency and the university must recognize the fluidity of the field of transportation planning. There are 5 areas in which changes are taking place, some more rapidly than others, but all at significant rates.

1. Methods of planning are changing rapidly. For example, the computer traffic assignment models and techniques for network representation are different from what they were 5 years ago and undoubtedly will be changed 5 years from now.
2. The types and extent of the data available are changing. Although the amount of

data does not seem to be increasing as fast as I would like, nevertheless there is more information available today then before, and this means that more different kinds of things can be done than before.

3. The content of the field of transportation planning is expanding very rapidly. Where 10 years ago transportation planning often was restricted in its meaning to urban transportation systems planning, today transportation planning must encompass corridor planning, project planning, impact studies, metropolitan systems plans for highways and expressways, rural transportation planning, transportation planning for special interest groups such as the poor, and statewide transportation planning. Statewide transportation planning in its own right has many subject areas including highway planning, planning for common-carrier person transportation, and planning for the movement of goods.

4. The number of persons who want to get into the act of transportation planning is increasing, and this includes citizens' groups and other special interest groups.

5. The pressure for useful and meaningful products of transportation planning is increasing. I believe there is a great danger that, if transportation planning becomes too "soft," too esoteric, and insufficiently relevant, the public will simply turn off the faucet. This has happened before in urban planning, and we should be aware of this reasonable demand for productivity and relevancy on the part of government.

This is the professional and organizational environment into which new graduates are moved, and it seems to me that there are 5 basic qualities and abilities that the graduate of a transportation program should have. These qualities and abilities are in addition to basic qualities such as intelligence, integrity, and courage, which are basic to one's rating of an individual.

1. The ability to write. Any product of a transportation planning program should be able to write simple reports quickly and effectively. Writing should not have to be taught by a consultant or a governmental agency.

2. The ability to do craftsmanlike work. Any product of a graduate program should be able to take a problem, stipulate what is given and what information is needed, determine the goals that affect choices, get data, propound alternative solutions, recommend a course of action, and write a report. The report should be documented, and the data should be appended and arranged in such a fashion that the next person can check what has been done. Such report writing should be done to a high level of accuracy. Standards of high-quality workmanship should be set in graduate school.

3. The ability to work with data. Much in graduate training is learning theories and learning facts and procedures of what has been done before. But just as a scientist should be able to work both in theory and in the laboratory, so the graduate student in transportation planning ought to be able to work with data. He or she should have actual experience in drawing samples, in interviewing people and measuring maps, in coding, keypunching, and checking data, and in analyzing data.

4. The ability to synthesize. So much is new in transportation planning that a premium is placed on a person's ability to bring together various pieces of information, to synthesize new theories, and to develop new methods. Simply applying old methods and solving problems by inserting numbers in existing formulas are not enough. The student should have training in developing methods. I believe that synthesis can be taught; some people will be better at it than others, but everyone that gets into a graduate school must have some of this ability. Architects are taught synthesis through the practice of designing buildings to solve human needs. The same can be done for transportation planners.

5. A creative skepticism. The graduate who comes out of school should be a skeptic, even of the methods taught in schools. Questioning is the habit of the critical mind. But this skepticism should not be carried to the extent of cynicism. The graduate must question, but ultimately he or she must do something as good as, or better than, was done before.

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