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.

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

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;

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

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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