Comprehensiveness in Transportation Education

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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.