Systems Aspects in Education for Transportation

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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 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.